LLOYD'S REGISTER STAFF ASSOCIATION

TRANSACTIONS 1952 - 3

VOL. 25

LLOYD'S REGISTER STAFF ASSOCIATION

SESSION 1952-53

President: R. Moffit

Committee:

T. W. Bunyan
E. Crossley
J. Irwin
E. L. Knowles
H. N. Pemberton
A. Reid
J. W. G. Thurston

Hon. Secretary: M. M. Parker
Asst. Hon. Secretary: R. P. Harrison

Past Presidents: S. F. Dorey
R. B. Shepheard
G. O. Watson
F. C. Cocks

CONTENTS

MARINE CORROSION ..... J. M. Murray

STEEL TUBES: MANUFACTURE AND SOME USES ..... F. Campbell & G. McFarlane

ALIGNMENT IN MARINE ENGINES
PART 1: TURBINES TO PINIONS ..... B. Hildrew

SYMPOSIA THE SURVEY OF VERY OLD SHIPS
THE REPAIR OF WELDED SHIPS

PRIVATE AND CONFIDENTIAL

LLOYD'S REGISTER STAFF ASSOCIATION

SESSION 1952-53
PAPER No. 1

MARINE CORROSION

By

J. M. MURRAY

LLOYD'S REGISTER OF SHIPPING,
71, Fenchurch Street,
LONDON, E.C.3.

The Author of this paper retains the right of subsequen publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals.

MARINE CORROSION

By J. M. MURRAY

THE subject of corrosion of steel has achieved much attention in technical circles since steel was introduced to shipbuilding. Many papers have been written on the subject—two which may be consulted with advantage have been presented to this association—Committees have considered the matter and investigations have been made.

The general principles governing the cause and the prevention of corrosion are well understood, but nevertheless corrosion, while not generally a serious problem, can often give trouble.

There is evidence to show that epidemics of corrosion of steel occur in cycles, and this is probably due to the fact that when there is a serious outbreak preventive measures are taken, and the shipping industry is more or less immune for some time until the incident is forgotten, precautions are relaxed, and the cycle starts over again.

About twenty years ago, Mr. J. Montgomerie, D.Sc., in the Transactions of the Institution of Naval Architects, expressed the opinion that "provided the surface of the steel is clean and provided that the paint adheres to the steel, there is no problem of corrosion such as we know it today." This statement has the merit of simplicity which may perhaps render it less acceptable than a more complicated pronouncement. Nevertheless, it contains the basis of the matter. Since Dr. Montgomerie's pronouncement was made, investigations into the cause and prevention of corrosion have multiplied, but nothing has been found which seriously contradicts the dictum.

MECHANISM OF CORROSION

At the present time, there has been some recrudessence of corrosion and therefore it may be of some interest to make a general review of the subject. Wasting of steel in the presence of seawater may be uniform or concentrated. In the first case it is generally called "rusting," and in the second "corrosion." In ship work the Surveyor is usually only concerned with the concentrated variety. If wasting was uniform, it would cause little anxiety, for an unprotected homogeneous plate free from mill scale loses only about ·004″ per year when exposed to sea water. Unfortunately, the Surveyor is not generally called upon to deal only with rusting; pitting or localised corrosion is the more serious trouble.

A short explanation of the mechanism of corrosion may be useful. It is now generally accepted that it is an electro-chemical action requiring both water and oxygen; the process is accelerated by the presence of an acid substance in the water. Steel exposed to moist air will rust rapidly and acquire a coating of iron oxide which stifles the action, but steel exposed to water will be affected to an even greater extent. Briefly, the theory generally offered is that when steel is placed in a salt solution such as sea water, particles of iron with a positive charge tend to go into solution and acquire a negative charge. At the same time, positive hydrogen ions come out of solution and form a film on the surface of the steel. This is removed by the oxygen dissolved in the water, and so long as oxygen is available the process will continue. The iron particles combine with the water to form rust, some of which adheres to the surface of the steel. Sea water contains sodium chloride and other salts in solution, and these salts help the transfer of iron particles for they tend to increase the number of hydrogen ions available for immediate discharge, in return for iron ions from the metal.

The concentration of hydrogen ions is expressed by what is known as the "pH value" of the solution, and this requires some explanation. If the concentration of the hydrogen ions exceeds a certain value then the solution has acid properties; if the concentration of hydrogen ions is less than a certain figure then the water is alkaline.

The concentration is expressed as the log of the reciprocal of the hydrogen ion concentration, that is, the greater the concentration the smaller the pH value. If the concentration of hydrogen ions is greater than $1/10^7$, say, $1/10^3$ then the "pH" value is 3 and the solution is acid. Conversely, if the concentration is $1/10^{10}$, the "pH" number is 10, and the solution alkaline.

The pH value of water has an important influence on the corrosive action and since in fitting-out basins the pH value is low, rapid corrosion may be expected there if any part of a ship's hull is left unprotected, either through paint being stripped or scored. Localised corrosion or pitting is due to a similar effect. If two dissimilar metals, such as zinc and copper are placed in contact in the presence of an electrolite such as sea water a small cell is formed; as soon as the current begins to flow, the pH value of the layer of water over the zinc falls, and the zinc is dissolved. In other words, the zinc is the anode and the copper is the cathode.

In more detail, the following are the reactions.

REACTION AT THE ANODE

Particles of zinc, with a positive charge, tend to go into solution, and in time the solution adjacent to the anode becomes concentrated, with the result that the passage of the zinc ions into the solution slows down. This effect is known as polarisation.

REACTION AT THE CATHODE

Hydrogen is evolved, and this combines with the oxygen in the water to form water. If the supply of oxygen is not sufficient, then the cathode becomes polarised. Further, a deposit of calcium and magnesium carbonates forms on the cathode.

An increase in the supply of oxygen results in the formation of insoluble corrosion products at the anode, making a protective film, which tends to polarise further the anode, while at the cathode the action is the reverse; there the oxygen combines with the hydrogen and tends to de-polarise the cathode.

In order to determine the effect of one metal on another in stimulating corrosion, it is useful to refer to the "electro-chemical series" and the usual order is that shown below :

Zinc
Cadmium
Nickel
Tin
Lead
Iron
Copper
Silver
Gold

In practice, if a metal at the upper end of the series is placed in contact with one below, the upper metal would tend to corrode.

CORROSION DUE TO MILL SCALE

Unfortunately for shipowners, mill scale comes into the series somewhere in the region of copper, and thus, if conditions are proper, it is a most potent stimulator of corrosion of steel. Mill scale on mild steel usually consists of several layers, a thin outer layer of red rust, or ferric oxide Fe_2O_3, a thicker middle layer of black magnetic oxide, Fe_3O_4 and a comparatively thick layer of ferrous oxide FeO, next the plate; of these the ferric oxide is the only stable oxide.

The proportion of the various kinds of oxide depends on the rolling temperatures. Plates finished at a high temperature have a thin, almost transparent layer of ferric oxide, and thus are black in colour and furthermore, if cooled slowly, then the oxide is formed in thin but tenacious layers.

It may be said that electro-chemical action due to the presence of mill scale is one of the most important forms of hull corrosion, and is more often than not the cause of localised pitting on the bottom and side shell of the ship which is often brought to the notice of the Surveyor. The action is accelerated by the presence of oxygen, and therefore the sides of the ship, where the water is more aerated, are more likely to be attacked in this way than the bottom. The remedy is, in principle, simple; either the mill scale must be removed completely, or the surface must be coated with a paint impervious to water. Since all paints are, in time, affected by hydraulic pressure, the remedy must lie in the former rather than the latter direction.

Corrosion due to mill scale is by no means a new phenomenon; it was first encountered in the late sixties not long after steel had been introduced to shipbuilding, and ten years later the British Admiralty, convinced that the only safe way to avoid trouble was by pickling the steel plates, started a practice which they have maintained ever since.

There is no doubt that pickling is the most effective precaution against corrosion which is available to shipowners. The process takes its name from the early practice of using vinegar to remove scale from iron. It is carried out by exposing the steel to a solution of dilute hydrochloric acid or sulphuric acid. The former acid has the more rapid effect. The exact concentration of the acid and the temperature of the solution depend on a variety of factors, but the acid baths used for pickling carbon

steels are generally 2 to 20 per cent sulphuric acid at 50° to 80° C., and 5 to 15 per cent hydrochloric acid at 20° to 35° C.

A modern development is the use of substances known as "restrainers" in the solution. These restrainers slow down the rate of acid attack on the steel, but do not prevent the removal of the scale. After removal from the acid bath the plate is washed and any residue of scale or rust remaining removed by wire brushing.

It is well known that dilute phosphoric acid has the effect of inhibiting corrosion, and the Footner process takes advantage of this fact. If the plate is subjected to the Footner phosphoric acid process an excellent surface is obtained to which the paint film adheres closely.

There are, of course, other ways of removing mill scale, and the general method is weathering and wire brushing. This may be effective if the steel has had time to weather, but in modern conditions this is not usually the case, and the mill scale which adheres very closely to the steel is not completely removed.

According to Mr. W. E. Lewis, B.Sc.—and his contributions to the whole subject of corrosion are such that it is evident that he, and not the present author, should be writing this paper—the weathering of scale covered plates is entirely dependent upon the action of the atmosphere upon the inner layer of ferrous oxide; oxygen and moisture from the atmosphere gradually changes the ferrous oxide to hydro-ferric oxide generally known as "rust." The principal layers of the scale are thus worn away from the surface of the metal and disintegrate. Mr. Lewis has shown that the scale on the hot rolled modern steel with the thick layer of ferrous oxide weathers more quickly than the scale on the older steel, but in modern conditions what happens is that some of the scale is removed while the rest adheres, and thus a non-uniform surface results. When an electrolyte in the form of sea water is added, there is a strong corrosive action, and this causes most of the trouble in the modern ship.

When considering corrosion caused by mill scale, it is important to remember that the intensity of the electro-chemical action set up depends on the relation between the areas of the anode and the cathode. With a large cathode and a small anode the corrosion at the anode will be rapid; with a small cathode and a relatively large anode the action will be less severe.

Mill scale is cathodic to mild steel, and therefore if only a small proportion of the surface of the plate is free from scale, corrosion will be rapid, and will take the form of pitting in the localities adjacent to the scale.

Riveting or welding has the effect of removing the scale in the vicinity of the rivets or of the welds, and this is one of the reasons that localised corrosion often occurs at these localities. It is not unusual to see a line of corrosion along a shell plate marking the position of a flat or deck welded to the shell. The mill scale on the surface remote from the welding has been removed by the heat set up during welding, and thus suitable conditions for corrosion are at hand.

In modern conditions, steel does not lie long in the stock yards; generally it is worked into the ship direct from the steelworks. As a result, it has not time to weather. The older cold finished steel, in spite of the more adherent scale, arrived at the ship in a more leisurely way and thus probably, was cleaner before it was coated with paint. There is some reason to think, also, that the older types of paints, with linseed oil in their composition, may have adhered better to mill scale than some modern quick drying varnishes.

Reliance on weathering, therefore, is bound to give variable results, and if pickling is not practicable then consideration should be given to the use of flame descaling; sand or grit blasting are not as yet applied to new construction.

There is a further advantage said to be gained from pickling the under water shell of a ship. The resulting surface is smoother than if weathering is adopted, and recent investigations have shown that this may have quite a significant effect on the frictional resistance of the hull when the ship is clean.

From time to time it has been suggested that if the ship is launched without the bottom being painted, mill scale would be removed by corrosion underneath the scale. Experience has shown, however, that this is not the case; all that happens is corrosion starts between the mill scale in adjacent patches of plate free of scale. It has been fairly well established that corrosion is far more serious if it starts when

a ship is new; if a ship survives the first few years of her life without corrosion, then there is not the same likelihood of trouble. For this reason, particular attention should be paid to the state of the outer bottom at the first dry docking after the ship is in service. At that time it would often pay to remove all the bottom composition down to bare steel and re-coat. Here it should be remembered too, that the protection afforded by paint is generally a function of the thickness.

CORROSION DUE TO ELECTRIC CURRENTS

It is known that one ampere of electricity is equivalent to 1·04 grammes of iron, and therefore electrical leakage is often advanced as a cause of corrosion. In the opinion of the author, if corrosion due to welding currents are excepted, this suggestion is completely erroneous. Poor condition of a ship's electrical installation resulting from earths on the system at different parts of the ship can have no effect on corrosion, for the condition is similar to that which exists in vessels having a hull return system in which all the current returns to the dynamo via the hull structure. It can be shown that the effective resistance of the hull is so much less than that of the alternative path through the sea water that the current naturally takes the former path.

With direct current welding, however, unless certain precautions are taken, there is always a danger that strong localised corrosion might result. The current of a welding electrode may rise to 300 amps if the electrode "sticks to the work" and if the generator is ashore, and there is no return lead from the ship to the shore, then it is obvious that severe local corrosion might result.

In that case, it is important to ensure that there is a proper return from ship to the shore. It is a sensible precaution to have the return duplicated, and it should be well bonded to the ship, so that it is not affected by the rise and fall of the tide. Alternating current is naturally much less effective in causing corrosion than direct current, and if the generating sets are placed on board the ship then the danger of corrosion is eliminated.

There is one source of danger, however, which may easily escape notice, and that is if two ships are lying abreast and a welder who is working on the inboard ship which has a proper electrical return is transferred to the outboard ship. If the outboard ship is not properly bonded to the other, then corrosion will result.

The necessity for a proper return cable when a ship is fitting out is so well known that there is perhaps little need to emphasise it, and the matter is mentioned here more to show that the omission of a return lead is a possible, rather than a probable, cause of corrosion.

CORROSION THROUGH TURBULENCE AND NOTCH EFFECT

This form of corrosion may cause considerable trouble and is responsible for corrosion at overlaps and the like. In the first instance, there is some localised corrosion due to the breakdown of the paint or to mill scale, or to other causes, and subsequently the action is accelerated by differences in the distribution of oxygen in the cavity thus formed. The corrosion is stimulated by aeration of the surface outside of the pit, which will be the cathode. The unaerated area within the cavity becomes the anode. This explanation has been given by Dr. U. R. Evans, who by means of a series of experiments, showed that if the oxygen concentration in a solution varies in different places, a difference of potential is set up in the steel between the areas of high concentration and those of low concentration; the areas shielded from oxygen in any way become anodic, and thus subject to corrosion.

CORROSION OF RIVETS AND WELDS

The Surveyor is not infrequently confronted with corrosion of rivets; corrosion of welds is much more uncommon. In essentials, the causes are the same in both instances. Paint adheres less closely to rivets and welds than to the adjacent plating, is more porous, and more easily rubbed off. Furthermore, there is turbulent flow at these localities, and the effect of unequal distribution of oxygen is felt, and in addition, there are areas clear of mill scale round the rivets and welds. It is probable also, that the rivet points themselves retain some scale; removal of the surplus material by chipping leaves a portion of the point free of scale, and a portion untouched. Altogether, conditions are most favourable for corrosion at rivet points, and fairly so at welds. Before attention was paid to the importance of homogeneous rivet material, the case was more serious, as there may be an electro-chemical effect within the rivet itself, as a result of segregation of impurities. Trawlers, and other craft subject to removal of

paint through scrubbing, may exhibit corrosion of rivets, and one trawler builder at least has introduced welding for the midship half length, so that, among other advantages, there will be no rivets to corrode.

The use of copper bearing steel for rivets has been suggested by Mr. W. Bennet, B.Sc., the advantage being that such rivets would be slightly cathodic to mild steel, and thus would not corrode. Here it may be remarked, incidentally, that copper bearing steel is not superior to mild steel in its resistance to sea water corrosion; on the other hand, it is more resistant to atmospheric corrosion, and to abrasion. As has already been said, corrosion of welds is less troublesome than corrosion of rivets. In some instances, however, it has been severe, and the wasting has been intensified by slag inclusion, which, naturally fall out when corrosion becomes active.

CORROSION OF ALUMINIUM

Generally speaking, the aluminium magnesium alloys are, by themselves, almost unaffected by the presence of sea water; the duralumin class of copper bearing alloy, on the other hand, are strongly affected, and for this reason, have no marine applications. Aluminium lies in the electro-chemical scale immediately above steel— some authorities put it at the same level as steel— and therefore it is strongly affected if placed in contact with copper. For this reason, it is unwise to use copper or mercury bearing antifouling paints on an aluminium alloy hull; the results can be disastrous if, from any reason, antifouling paint of this description comes into contact with the alloy. It may be stated here, incidentally, that quite serious damage has been done to steel through the same cause, but this is most unusual, for the anti-corrosive coating offers an effective barrier. Aluminium alloy, of course, does not require an anticorrosive undercoat. It is usual to require that steel in contact with aluminium alloy should be galvanised, a sensible precaution, though one which has been contested on the grounds that steel and aluminium are at the same, or nearly the same, potential. Similarly, it has been suggested that steel rivets can be used in aluminium without danger, but tests have convinced the author that this is not so for under-water work. However, this matter will in time be of little importance, for welding will inevitably replace riveting in aluminium alloys.

CORROSION DUE TO DISSIMILAR METALS

It is apparent from what has already been said that when dissimilar metals are brought into contact in the presence of sea water, corrosion will occur, and this is seen in the corrosion which takes place at the stern of ships fitted with bronze propellers. The mechanism is that the propeller is cathodic to the steel, and therefore iron ions tend to go into solution at the anodic areas.

For many years it has been the custom to attempt to prevent the corrosion of the stern of the ship by means of what is known as "sacrificial protection." Zinc blocks are fitted to the hull of the ship in way of the propellers, the argument being that as zinc is strongly anodic to both bronze and steel, it will give protection to both. Laboratory experiments have shown that with such a three metal system a zinc block one fifth of the area of the steel is required to protect the steel, and even more unfavourable results have been observed. In practice, as a result of the build up of corrosion products on the zinc, polarisation is rapid, and substantial protection is afforded for a very limited time. Furthermore, to obtain any benefit from the system, the zinc should be bonded intimately to the steel, a circumstance which rarely obtains in practice. The rather doubtful efficacy of zinc protectors is often completely eliminated by an over-zealous application of paint to the protectors as well as to the rest of the hull. In the opinion of the author, zinc protectors at the stem of a ship are completely useless; a preferable substitute is a coating of high duty protective.

ANAEROBIC CORROSION OR CORROSION WITHOUT OXYGEN

As a matter of interest, mention might be made of this peculiar form of corrosion which has been observed frequently in steel piles driven into mud, water pipes buried underground and the like, but which is fortunately very rare in ships. This type of corrosion can occur through the action of sulphate reducing bacteria.

It is stated that these bacteria are of two varieties, one acting on sulphur containing inorganic matter and producing sulphuretted hydrogen, which destroys the paint film, and the other acting on sulphates and producing sulphides which promote corrosion of the metal. Corrosion produced in this way is more likely

to occur in tropical regions, though corrosion of a new ship which lay on a mud bank during hot weather in this country has been so explained. Anearobic corrosion is probably a card which should only be played as a last resort, though the author was once told by a superintendent with very keen eyesight that he had seen the beasts at work.

CATHODIC PROTECTION

Since corrosion is caused through a current between anodic and cathodic elements in the hull, it is evident that if a hull as a whole could be made cathodic by means of an impressed current, there would be no corrosion. Theoretically, it should be possible to apply a uniform current to the hull, but in practice there are difficulties. The system has been applied to steel piling, water mains and the like, but so far it has not passed the experimental stage on ships.

In 1948 experiments were carried out on a Canadian minesweeper of the "Algerine" class. The system consisted of 10 magnesium alloy anodes weighing about 80lbs each which were secured to the bilge keels of the ship and insulated from them and also, naturally, from the hull of the ship. After a year in service no corrosion of any importance was found on the underwater hull, the general condition of the paint was fair, and there was little fouling growth. About half of the anodes were consumed in the year. Check tests carried out on a sister ship gave similar results, and as a result the Royal Canadian Navy have fitted a cathodic protection system using magnesium alloy anodes to seven ships. There are two points to be borne in mind here; one is that the ships are of relatively small size, and the second is that the current induced by the magnesium anodes can be controlled. Herein lies the difficulty: if the current is lower than a certain optimum value, the ship will not be protected, whereas if it is greater, the alkaline deposits on the hull and the permeation of the water through the paint under electrical and osmotic forces will cause blistering of the paint and rapid breakdown. More recently a similar system using three tons of anodes has been applied to an American tanker, but it is too soon to pass judgment on the matter.

A further step which has already been taken is to use steel anodes and an impressed current from a generator. Here, also, the current has to be carefully regulated and the hull potential maintained within very narrow limits.

There is no doubt that certain paints are less seriously affected than others by the alkaline deposition, and in time this method of protection may become standard. For obvious reasons, however, it is likely to gain favour in the first instance in Naval ships rather than in merchant ships.

CONCLUSION

These remarks deal primarily with the phenomenon of corrosion, and the way in which it may be minimised or prevented. The complete removal of mill scale is regarded by the author as the most important step in that direction. No attempt has been made to deal with the extremely complicated subject of protective coatings. These would require a paper in themselves, and a knowledge which the author does not possess. All that need be said about anti-corrosives here is that within reason the thicker they are the better. To start and to sustain corrosion, sea water is required, and if the sea can be kept away from the ship then no trouble should result. A paint completely impervious to sea water would be a complete solution. Unfortunately, such a paint is not available.

Mention might be made of two systems which are giving promising results at the present time, an aluminium pigmented bituminous base paint, and a primer having a basis of polyvinyl butyval resins which has both good adhesive and anti-corrosive properties.

In the experience of the author, the protective value of an anti-corrosive varies directly with the price; it is for the shipowner to decide whether a high outlay and low maintenance charges are preferable to the reverse.

No mention has been made here of internal corrosion of oil tankers. This is such an important matter that it deserves a paper to itself.

PRINTED BY LLOYD'S REGISTER OF SHIPPING AT THE SOCIETY'S PRINTING HOUSE, 64, SOUTHWARK STREET, LONDON, S.E.1, ENGLAND.
SEPTEMBER, 1952.

PRIVATE AND CONFIDENTIAL

LLOYD'S REGISTER STAFF ASSOCIATION

SESSION 1952-53
PAPER No. 2

STEEL TUBES: MANUFACTURE AND SOME USES

By

F. CAMPBELL and G. McFARLANE

LLOYD'S REGISTER OF SHIPPING,
71, Fenchurch Street,
LONDON, E.C.3.

The Authors of this paper retain the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals

STEEL TUBES: MANUFACTURE AND SOME USES

By F. CAMPBELL and G. McFARLANE

SCOPE OF THIS PAPER

IT is proposed in this paper to give a brief account of the development of tube making and the present-day methods of manufacture of both welded and weldless tubes, together with some of the uses to which tubes are put. It is not intended to be a technical treatise or to deal with problems of design or manufacture, but is concerned only with the types of steel tubes with which the Authors have been associated in the course of their duties.

It is hoped that, however restricted its form, it may be found of some interest and service to colleagues whose duties afford them only limited dealings with tube making.

MANUFACTURE

For convenience, tubes may be classified as welded or weldless and it is under these general headings that it is proposed to consider their manufacture. Before dealing with the various processes of manufacture, however, it is desirable to give some thought to the quality of steel required by the tube-maker for a particular process.

For furnace welded tube, weldability is of fundamental importance, and as the effect of carbon and certain other alloying elements is to retard this property, the steel used for this type of tube must have a relatively narrow range of composition and physical properties—carbon about 0·18 per cent and say 28-32 tons per square inch tensile strength. Steel is supplied strip or plate.

For weldless processes the limitation as regards weldability does not apply and therefore a greater range of steel composition and mechanical properties is available. According to the particular process employed the form of the material is either squares or rounds or in the pilger process cast steel ingots may be used.

WELDED TUBES

In dealing first with welded tube, the material used is a flat strip which is first rounded up to tubular form and then welded longitudinally by one of several methods depending on the size and subsequent use to which the tube may be put.

The essential basis of these processes, no matter how they are carried out, is the welding operation. The term "welding" covers two distinct operations both of which are used in modern tube making.

True welding consists of uniting, by heat and pressure at sufficiently high temperatures, the metal surfaces between which a joint is required. It is essentially the union of the molecular units of the steel into a homogeneous whole and when carried out successfully, the joint has all the strength and characteristics of the raw material used. Without discussing the theory of this operation, two essential facts stand out clearly and must be given consideration.

1. The uniting surfaces must be free from interfering surface films if complete metallic union is to be obtained.
2. As fluid oxides are flowing on the surface of iron and steel at the temperatures employed these must be eliminated to secure the complete union. Good welding steel, therefore, must be such that these oxides formed at welding heat would be capable of being expressed under pressure.

The second type of welding is that known as Autogeneous welding. In this process the edges of the joint are melted either by oxy-acetylene flame, or by electric arc, and any deficiency is made up by the filling material being added or obtained from the arc point itself, i.e. the electrode. Theoretically, the joint is made by fusion of the edges being welded. The technique of welding by this method has now reached a

very high degree of efficiency. There is also, of course, the process of electric resistance welding which is being increasingly used in the manufacture of steel tube.

The art of welded tube making consists of producing continuous weld over considerable lengths (20 feet and upwards) in large numbers.

The types of welded tube made are :—

(a) Butt Welded

(b) Lap Welded

(c) Water Gas Welded

(d) Electrically Welded

BUTT WELDED TUBES

This process is made for smaller tubes up to 2½ in. diameter. It is the simplest process in point of number of operations, but requires a high degree of weldability in the steel and good facilities for the rapid handling of large outputs.

The material which is in strip form is pushed into the heating furnace by a charging apparatus. When heated to the correct temperature the strip is gripped by tongs attached to a draw bench and pulled through a funnel shaped die which causes it to curl into the tube form and presses the edges together, welding them, the width of the strip being a little greater than the circumference of the tube so that the required pressure can be obtained in the welded seam. Both the charging machine and the draw bench can traverse the whole width of the furnace working backwards and forwards. The hearth is thus always full and the process is practically continuous. After the tube is formed the tongs are detached and the hot tube is passed through rolls which round it to correct size, thence to a straightening machine, and on to cooling racks. When cool it is transferred to the finishing shop, cut to size, ends prepared for screwing or otherwise made ready for jointing, tested and finished for inspection and despatch.

It is computed that the welding of tube by this process is about 300 feet per minute, yet it should be noted here that very remarkable mechanical test results are obtained by this method and the tubes can be expanded to about 50 per cent of their diameter without fracture, and tensile tests across the weld give figures similar to the strip itself. The butt-welding process described above is the one in common practice here, but a later method has been developed in which, instead of strip material cut to given lengths being used, the material is coiled on reels and is fed in one continuous strip through a furnace of special design. It should be stated at this point that the authors have not had the opportunity of witnessing this process but they have been informed that the resultant weld is so consistently good that, for many purposes they are displacing seamless tube. For the sake of interest a short account of the technique employed is given. The strip in a coil is placed on an unreeling drum. As the strip unreels it passes through a levelling machine to the flash welding unit where the end of one coil is welded to the start of the next. The flash welder comprises a butt welding head and a flash stripper both being fully automatic. The total time taken for the complete welding and stripping operation is about 20 seconds.

The strip then passes to the furnace via a long inclined slope on which it forms a loop, the purpose of which is to allow the mill to continue to draw the strip through the furnace whilst the flash welding is taking place. On emerging from the furnace at a temperature of about 1400° C the surfaces of the strip are cleaned by means of air blasts before it enters the first pair of rolls in the welding train. These rolls form the flat strip into a circular section with a slight gap between the edges.

The edges are again cleaned by air jet and pass to the second pair of rolls which exert sufficient pressure on the formed strip to weld the abutting edges together. Four more sets of rolls serve the purposes of consolidating the weld and drawing the strip through the train. The speed of the strip in its passage is from 2-4 feet per second according to size of tube being welded.

The red hot tube leaves the rolls in a continuous stretch and is cut to lengths by a flying saw, which is synchronised with the mill drive. The actual lengths cut can be varied while the mill is running.

The cut lengths of the tube travel on a roller trough to the first cooling rack, through sizing and descaling rolls to a second cooling rack where "hot" examination takes place. Leaving rack No. 2 the tubes are still too hot to handle and they pass through a cooling spray before delivery to the milling machine. There the ends are faced square and subjected to first cold examination. They are then passed to the finishing shops.

LAP WELDED TUBES

There are several variations in the sequence of operation followed in making lap welded tubes which can be made in sizes from 2½ in. to 15 in. but only a typical outline of the process will be given. Commencing with the flat strip or plate this is scarfed, i.e., the edges are bevelled to ensure that there shall be no excess of steel at the joint beyond that required to give good welding pressure and a tube of uniform cross section.

The scarfing is done either by cutting the plate edges cold on a planing machine or by heating and rolling. If the former method is followed the strip is then heated to 900° C or, if the latter, the hot strip is taken direct to the turn-up bench. This is a draw bench fitted with a suitable die and mandrel.

The hot strip is rounded up to tubular form, the two bevelled edges being left overlapping in position for welding. It is then transferred to the welding furnace where it is heated to welding temperature. In front of the furnace are the welding rolls which consist of two rolls of the approximate o/d of the tube. Held in the opening between the rolls by a bar behind is the plug which gives the final tube its correct inside diameter and, when adjusted with the roll opening, the correct thickness of the tube wall.

The rolls are rotated towards the plug and bar and the rounding up piece—now at welding heat—is pushed up to the rolls and plug which grip it and pull it through, the pressure between the rolls and plug, at the temperature of the piece, welding the overlapping portion. The mandrel bar—which is now through the welded tube—is withdrawn by a suitable mechanism, the plug dropping off. The hot tube is then passed to a live roller rack which passes it to the sizing rolls where it is given the final correct diameter and any excess scale broken off. The tube then goes to specially turned obliquely placed rolls which straighten it. The tube then goes to cooling racks and when cold to the cutting-off machines and thence to the testing and finishing shops.

WATER GAS WELDED TUBES

By this method the tube is also made from plate material, but whereas in the butt and lap welding methods already described the whole of the seam had to be brought to welding heat at the same time, in this process only part of the seam is heated and welded by hammers or rolls. After one part is heated by gas, usually about one foot in length, the hammer or roll is applied and the part welded. The next part is heated and welded and so on until the tube is completed. The advantage of this process is that not only tubes but cylindrical containers of large diameters of varying thickness can be welded. It is also possible to have two seams where the diameter cannot be obtained from one sheet. Bending of the sheets can be done either hot or cold and, after bending, the seams are tacked by gas or electric weld or held by screws so that the diameter is maintained and a uniform weld is obtained at all points. No bevelling of the edges is required and the lap of plates is never more than twice the thickness of the plate. The tube is then placed on the rollers of a wagon so that it can be rotated or moved backwards and forwards; the wagon rollers also can be raised or lowered, thus enabling the tube to be moved over the anvil bar of the welding machine. In front of this anvil is a burner with a gas flame (water or coke oven gas) which heats the seams from the inside. Opposite the burner is an outside burner heating the top layer of the lap. When the section of the seam is brought to the required heat the wagon is moved backwards a little until, on the anvil bar behind the burner, the tube is lowered. Above the anvil is a compressed air hammer or a movable pressure roller operated hydraulically. The heated section is then welded into a seam by the hammer or roller and this repeated until the whole seam is welded.

After welding, the tube is heated in a furnace and passed through a rounding roll. It is then examined along the welding seam and if any small defects are detected the tube is taken to the dressing bay where, under supervision, the defects are cut out and repairs carried out by coal-gas or acetylene welding.

The tubes are then fed through a sizing machine which ensures that the size and roundness are within the tolerances claimed by the Makers.

It should be of interest to note here that when tubes of this type are required for fabrication purposes, and may be cut to shorter lengths for the fittings of slip-on or weld neck flanges or the matching of ends for butt welding joints, it should be specified that a certain percentage of the order be sized "all over".

The general practice of the manufacturer is to ensure that the ends of all tubes made by this process conform to size in accordance with their claimed allowance and the body of the tube may exceed this slightly. Tubes made by this process are usually of a size not yet made by the seamless process in this country and can be used for fairly high pressure work and temperatures.

METAL ARC PROCESS

This process, as the name implies, is the welding of the seam of the tube by manual or automatic electric welding and does not call for discussion here. It would be of interest, however, to point out that tubes made by this process are always required to conform to a particular welding specification and that this is adhered to should be the primary concern of the inspecting authority.

ELECTRIC RESISTANCE WELDING

This method of tube manufacture is becoming ever more popular for the manufacture of boiler tubes and is also finding a growing demand in the oil industry. A feature of tubes made by this process is the uniformity of wall thickness thus ensuring concentricity of bore. While the actual methods employed may vary in different mills, the principle remains similar.

The strip is planed at its edges, cleaned of all scale and then accurately formed into a round section so that the edges are flush against each other forming a close seam. It then goes into the welding machine, the design of which is fundamentally the same in all types, i.e. hard copper rollers run on the right and left of the seam through which an electric current of high amperage is conducted. The seam, which, because of its high resistance, becomes heated and soon reaches welding temperature. The tube is moved forward by the calibrated rolls and the edges brought together under their pressure thus forming the weld, the excess material being pressed outwards and inwards. A further set of calibrated rolls, a short distance away from the point of welding, brings the tube to correct size and roundness. The external and internal excess of material is at the same time removed and the cross section through the weld is practically the same as the rest of the tube.

TUBE EXPANSION

Tubes already formed can be altered in size, i.e. diameter, by expanding. This method of supplying a demand for tubes with a thin wall is more commonly used in continental mills than in this country but it occasionally is resorted to here.

The method adopted is to heat the tube in a furnace then to place it on a bed with a travelling bogie passing along the tube length on the underside. One end of the tube, which has been bell-mouthed, is caught in shaped dies fixed on a rigid frame. A shaped plug on the end of a mandrel bar is then inserted into the tube at the fixed end and, by hydraulic pressure, is pushed along its length.

When the plug is pushed clear of the tube it falls off and the mandrel bar is withdrawn. The expanded tube which is now slightly larger than the desired finished size is reheated in the furnace to a given temperature, withdrawn and passed through sizing rolls which also smooth the outer surface. After straightening, the tube is passed to the finishing shop and thence for inspection and testing. This method, as has been said, is not commonly practised for steel tubes in this country and is not economical but the authors cannot pass any comments on the practice as used elsewhere.

It should be noted that during the expanding operation it may sometimes be found necessary to maintain the required heat on the tube at the plug travel point by means of oxy-acetylene flame and this is done by a suitable arrangement being fitted to the travelling bogie.

WELDLESS TUBES

For weldless tubes as compared with welded tubes, a greater range of steel, as regards composition and mechanical properties, is available and it is now possible to produce tubes of very high mechanical strength and other properties not only in higher carbon but in alloy steel and in alloys.

Much could be written on the development of the production of weldless tubes commencing with the method of boring out solid bars mechanically and then drawing the resultant hollow bloom. Such a sequence of operations was actually in use until comparatively recent

times. In the making of a weldless tube, therefore, the methods adopted fall into two clearly defined processes :—

(1) To make a hollow bloom, and

(2) To elongate the bloom obtained to a finished thin walled tube.

Taking first the question of securing hollow blooms from solid billets, there are two broad classes into which the piercing methods may be divided :—

(a) Static pressure, and

(b) Rotary piercing.

(a) Static Pressure

These methods are all variations of the one idea as evolved by Ehrhardt and familiarised by the production of hollow shell blanks in suitable presses. A solid bar of suitable cross section is placed in a container in a press and a hole made in it by entering a suitable plug under pressure by means of a power operated ram. In some cases the hole is made right through the solid bar, but in others it is only partly through and a solid end is left. This is dependent on the subsequent rolling and drawing practice followed.

(b) Rotary Piercing

This is at present the most popular system of securing hollow bloom and is said to have been invented by two German brothers, R. and M. Mannesman. The theory of the process is that when a solid metallic cylinder is rotated between rolls operating obliquely on its circumference the mechanical action produced causes the centre of solid to cavitate or become hollow (Fig. 1). By adjustment of the angle of the rolls to one another and also their profile, it becomes possible to feed the bloom forward as the hollow centre is produced. In practice the hollow bloom is fed forward over a suitably placed mandrel and the thickness of the bloom wall can thus be controlled. It might be well to state here that a special feature of this process is that the rolls rotate in a singular direction.

The same effect can also be produced by substituting rotating discs for rolls and such piercers, operating commercially, are known as Stiefel Mills, this development having been introduced by a certain R. C. Stiefel (Fig. 2 & 3).

A round rolled steel bar is used in these rotary piercers and for some classes of work round cast steel ingots.

Three ways of producing tubes from the hollow blooms prepared by either of the foregoing methods are in common use :—

(1) Dies.

(2) Rolling.

(3) Pilgering.

Push Bench

When dies are used the hollow bloom with an end left solid is fitted on to a bar and, on this bar, is pushed through a series of dies in a bench. The thick hollow blank is thus reduced internally to the diameter of the bar and the thickness of the tube wall is determined by the size of the finished die used. The tube is then eased from the bar in a reeling machine and the bar extracted. The solid end is cut from the tube which is then ready for finishing.

This process, known as the push bench or Ehrhardt process, is commonly adopted for small sized tubes (Fig. 4).

Draw Bench

This process is practically the push bench in reverse and the two operations are often worked in conjunction with each other.

Tubes of the smallest sizes of which the mills are capable are produced by the "hot" processes and these are transferred when cold, and after tag ends have been formed, to the draw bench where, by suitable arrangement of dies and mandrels, the tubes are drawn and progressively reduced to the required size (Fig. 4a).

Rolling

In rolling methods the usual practice is to roll by a number of passes over a mandrel. In the Automatic Mill (Fig. 5), which can be taken as typical of this class, the completely pierced bloom is forced against the rolls behind which is placed a mandrel (usually referred to as a plug) held on a rigid mandrel bar fixed in a rack behind the mill. The rolls grip the hollow and roll it over the plug. When the tube is through the mill it

remains on the mandrel bar, the plug is removed and the top roll lifts. An auxiliary roll then engages the rolled tube drawing it off the mandrel bar and passing it through the opened rolls to the entry side of the mill (Fig. 5a). The operation is repeated for two or three passes which are usually sufficient to produce the finished tube. The method described is that used for tubes from 2 in. to 5½ in. diameter. With certain modifications this process is now used for the production of tubes up to 14in. diameter.

A thick walled hollow of smaller diameter than the finished tube, pierced in a rotary piercer, is put through a second piercer which really functions as an expanding mill. By adopting suitable roll profile and mandrel characteristics the original thick walled hollow bloom from the piercer is expanded to the correct diameter for rolling in the automatic mill in a similar manner to that already described for the 2 in. to 5½ in. sizes.

Tubes of all sizes, after leaving the automatic mill, pass to a reeling machine in which the diameter is increased slightly by passing over a mandrel. The tube is then passed to a mill of three or more stands where it is finally finished correct to size and passed to the cooling racks. Tubes made by this process are of a very good surface finish and of good concentricity of bore (Fig. 5b).

Pilgering

The third method of bloom reduction to finished tubes is by the Pilger process. By this method a range of sizes from 4 in. to 10¾ in. diameter can be made on the same mill and, by the same plant and on another mill with the appropriate plant, tubes from 10¾ in. to 16 in. and 18 in. can be made. For the production of large or small quantities of each size and the quick change over from any one size to another, within the range of the mill, this method has been developed in this country.

A feature of this process which is outstanding and is of special interest from an inspection point of view is the fact that for most qualities of tube the processing is done direct from the ingot and the ingot becomes the whole surface of the tube. A great deal might be written on the technical and economical aspects of the process, but only a short account of the method can be given here.

The hollow bloom, from one or the other methods of piercing, is fed over a mandrel bar. This bar is then attached easily but positively to the front of a carriage which is part of the feeding arrangement (Fig. 6). These feeding arrangements are complicated mechanisms for which there are several patents, but the principles remain common in that for each revolution of the rolls the hollow must be fed forward a controlled distance in the direction of its length and on the backward movement, while the rolls lift, the hollow will be rotated through approximately 90°.

The mill itself consists of two rolls rotating against the direction in which the tube is to travel. These rolls are so cut that only a portion of the circumference will bear upon the bloom at each stroke of the feed bar. The effect of this is to forge out the hollow bloom as a tube, the holding bar acting as an anvil and the rolls, by their shape and direction of rotation, acting as the hammer.

Fig. 6a shews a sketch of a set of Pilger rolls and Fig. 6b illustrates the forging effect.

By rotating the bar and making suitable roll adjustments it is possible to feed the finished tube through the mill until the whole hollow bloom has been forged out as a tube. The mandrel bar is then extracted and the tube passed to the finishing operations.

Fig. 6c shews a typical layout for a Pilger mill.

SUPPLEMENTARY PROCESSES

Upsetting, Rounding Operation, Etc.

Upsetting is a further operation on finished tubing. It is often necessary to form the tube at its ends and so facilitate joining, screwing or flanging. One common means of making such preparation is by the use of a "staver". The process is not peculiar to seamless tubing only and, on tubing made by the welding processes, it can be used with success.

Fig. 7 shows a diagrammatic sketch of a staver layout. The tubes handled, which as an example vary in length up to 50 ft. and range in diameters from 2⅜ in. o/d upwards, pass from the rack to the furnace and thence to the Staver. The

vertical ram carries the dies and acts as a clamp for the tube, the horizontal ram carrying the plug. By changing plug and dies a variety of sections can be obtained and some of the more common are shown in Table (1).

TABLE (1)

(*See also sketch on Page* 14)

Long Sleeve Joint—for lead and yarn packing.

Short Sleeve Joint—for lead and yarn packing.

Sleeve—for weld.

Spherical End—for weld alignment.

Loose Flange Joint.

External Upset.

Internal Upset.

Victaulic Joint.

A considerable quantity of external upset tubing is subsequently screwed at ends for use as casing and drill pipe in the Oil industry.

TUBE FORGINGS OR BUTT WELDING FITTINGS

Butt welding fittings are used in large quantities in pipe assemblies in the Oil industry. By their use the designer can save space and weight by eliminating the necessity of tube bending and the need of heavy flanged sections. There can be a close nesting of oil and feed lines etc., and the replacement of parts simplified. All Oil Companies carry stocks of such fittings and the necessity of manufacturing these fittings to fairly close tolerances will be appreciated.

The specifications covering the manufacture of butt welding fittings are B.S.S. 1640 and the A.S.A. B.16-e.

Some comments on inspection requirements will be found in a section of this paper headed "Inspection".

A few details of the forms of the fittings and the methods of production now used are given herewith. 45°, 90° Elbows with long and short radius and 180° return bends are made as shown in Figs. 8 and 9. The shaping principle of forcing a tube length over a mandrel somewhat larger than the bore of the tube is common to all methods. The heating of the tube differs in each case, as do also feed arrangements. The resultant fitting does not vary much whichever method is adopted.

Fig. 8 shows a diagrammatic arrangement of the adjustable burner plant. In this the forging is allowed to turn upwards while adjustable burners play over the section being forged. The tube lengths are tack welded as shown—this tends to minimise twisting and buckling as the work passes over the mandrel—and on passing over the mandrel the working heat is sufficient to burn away the tack. When formed, the forging passes to the workshop services for cutting, bevelling, pickling and stove enamelling as required. In Fig. 9 the forging is allowed to turn downwards into a floorpit while the heat is applied by means of an oil-fired furnace built around the mandrel.

By another method the heat is induced by the winding of electric coils around the tube on the bar attached to the mandrel and, by the passing of a high frequency current, a heat of fixed temperature is obtained. In this method the turn can be made either upwards or downwards to suit circumstances. The length of the tube fed to the former governs the size of elbow produced with regard to angle. It will be obvious to the reader that the 180° return bend demands the greater length while the 90° elbow requires a shorter length. By "cutting down" 180° bends it is possible to supply any required angle of fitting. The diameter of the formed tube is subject to considerable expansion when passing over the mandrel, e.g., an 8⅝ in. o/d x ·322 in. thk. 90° long radius elbow is produced from 6⅝ in. o/d x ·432 in. thk. tubing and it is essential that seamless steel tubing of high quality is used for the manufacture of butt welding fittings.

Tees, equal and unequal, caps, etc., are made either by forging with dies under a forging hammer or an hydraulic press. These are made in several stages and are of the extruded type. This method is similar to the Ehrhardt process (Fig. 10). Reducers are also made by hammer or hydraulic press but in this case forging practice is used and a great range of sizes can be obtained.

Owing to the severe tests to which the tube is subjected by the forging processes, it is essential that the quality of the tube be maintained to specification requirements and great care should be taken to see that defects inherent in the tubes are detected when examining the completed fittings.

It is not possible, on an economic basis, to test by hydraulic pressure the butt welding fittings when manufactured, but each manufacturer should be

asked from time to time to submit samples of their products to a bursting test and to furnish a certificate of the results.

It is an essential factor that there is an adequate system set up by the manufacturer of such fittings to examine each item throughout each stage of manufacture for quality and to ensure that they conform with the requirements of the specification and order. It is also desirable, indeed imperative, that the Makers devise some foolproof method of identification of the fitting with the tube batch and cast from which it comes. To ensure that this is in being should be the first duty of the Surveyor in attendance at the works.

PARTICULAR USES IN THE OIL INDUSTRY

Before inspecting oil pipe, whether it be seamless or welded, some consideration must be given to the duties required of such pipe. To Surveyors unfamiliar with the various types of tubing commonly used in oil installations, some brief details of a well programme may be of interest and make for a better appreciation of the types of tubing to be discussed.

The depth of an oil well is dependent upon the level at which oil is located within the earth's formation. The geological formation varies in its make up and each well has, to some degree, its peculiar characteristics. (*See* Fig. 11.) Well diameters vary with increase in depth—e.g., a deep producing well may be around 14,000 ft. and these diameters may vary from about 16 in. at the surface to around 6 in. and smaller at the bottom. As drilling is continued the walls of the well tend to cave in and water seepage from the surrounding strata is encountered. To obviate this trouble and eliminate contamination, the well is lined with steel tubes known as "casing". It will be readily appreciated that casing generally should be of the seamless tube type owing to the great external pressure imposed on the tubes. Leakage also would lead to inefficiency of the plant. A typical casing order for a well of about 12,500 ft. deep may be :—

15 in.	dia. down to	500 ft.	
11 in.	„ „	4,000 „	
8 in.	„ „	7,000 „	
6 in.	„ „	12,500 „	and cap rock.

The build up of such a string is suggested in Fig. 12.

Casing is supplied in 18-40 ft. lengths according to diameter and coupled progressively as the well drilling proceeds. The casing collars, drill pipe and tubing (*see* Fig. 12) show the make up of the string and are purely diagrammatic. The necessity for these pipes to be straight and of good quality will be obvious. Faulty drill pipe, tubing or casing gives serious trouble at the site and often is the cause of "stickers" or in some cases a lost well. "Fishing" for a bad tube section in either drill pipe tubing or casing is a costly business and it may sometimes be quicker and cheaper to drill a new well.

When cap rock is reached and the well has been drilled in the oil comes to the surface by means of the annulus between the casing and tubing. This may be effected by the field pressure alone or by suitable pumping arrangements. Whatever the method adopted, the oil, on reaching the surface, is conveyed and processed through various sizes and types of linepipe. The requirements of such piping are more relaxed than those of the forms already discussed.

1. Casing, Drill Pipe and Tubing

The requirements of these forms of piping are very thoroughly covered in the American Petroleum Institute Specification 5A. The necessity of ensuring straight lengths has already been noted and the limits laid down for the threads ensure that there will be no danger of misalignment along the well strings when assembled. In general, seamless quality material is used for casing, drill pipe and tubing, but in certain cases welded tubing is acceptable. It is emphasised in the specification, however, that the weld jointing must be undertaken by a method whereby no extraneous metal is added to the joint.

2. Linepipe

The requirements of linepipe are covered by the American Petroleum Institute Specification 5L and this specification covers both screwed and coupled or bevelled or plain end types. The form of linepipe ordered depends largely on its duties and often becomes an economic consideration. Linepipe is more readily accessible

in the event of tube failure and, where pressures permit, very often manually welded pipe serves the purpose required. Leakage in the case of overland piping or linepipe for use in fabrication can be traced and quickly rectified. Underground piping is not uncommon and for this duty seamless quality material is usually demanded.

3. Still, Condenser and Boiler Tubes

Tubes used for any of the above items are in all cases adequately covered by a relative specification in the American Standard Code so far as the oil companies' requirements are concerned and by corresponding British Standards when used for marine work. The Society's Rules also give the requirements for boiler, superheater and smoke tubes, and little can be added here except that in all cases of tubes required for one of the above purposes only open hearth or electric furnace produced steel should be accepted.

4. Still and Furnace Tubes

Tubes for stills and furnace use are of low carbon, carbon molybdenum and chrome molybdenum material. The specific requirements of each type are laid down in the relative A.S.T.M. Specification. A feature of these specifications which should be observed is that, in addition to other physical tests, Brinell or Rockwell hardness tests are also required. Bore and o/d tolerances are specified and means of checking these should be supplied.

Particular attention should be paid to the grinding of the ends of the tubes and a smooth finish should be requested to facilitate examination for end cracks and fine surface laminations.

FABRICATED PIPEWORK

There is a big demand within the Oil industry for welded pipe assemblies. It is possibly one of the largest users of this type of fabrication. Some idea of quantities may be given by these figures quoted by Gardner in a recent paper on "Quality Control of Fabricated Pipework." In this he gives :—

Estimated erected cost ...	£28,000,000
Process plant	£10,000,000
Steel pipe and fittings ...	£1,800,000

These apply to a new Refinery processing 2½ million tons per annum.

To Surveyors unfamiliar with the practical aspects of this type of work, there are certain requirements demanded. It is general practice to manufacture fabrications from material in accordance with API-5L Standards. The tolerances on pipe sizes under the requirements are :— Outside diameter ± 1%; wall thickness ± 12½%. By this there is a reasonable agreement as regards working and joint alignment tolerances among the various works engaged in fabrication. In works recognised for this type of work there is a welding procedure and operator qualification as detailed under the Standard American Code for Pressure Piping ASA. B31-1B 1951. The requirements of this Code must be rigidly adhered to and the works procedure and welders' qualification tests should be to the satisfaction of the Society's Surveyors.

The bulk of process pipework for oil industry comprises straight or bent tube upon which has been welded flanges, tees, elbows, reducers, caps, etc. Pipe diameters may vary from 2 in. bore up to 16 in. o/d with thicknesses up to ½ in. The major oil companies have their individual specifications for fabrication of welded pipework, e.g., the A.O.I.C. Standard Specification No. 167/11/50 is recognised by the Society and sets forth the requirements of welding procedure and inspection to be adopted. In general these specifications lay down a minimum acceptable standard. Welders engaged upon fabrication are retested periodically or when the Surveyor in attendance has good reason to question the welders' ability in the work. Inspection facilities are placed at the service of the Surveyor and quality checks are made by either trepanning a section from the weld or by gamma ray or radiography of the welded joint. The trepanned sections are prepared and etched to reveal any faults or inclusions which may be present in the weld. A diversity of opinion exists regarding the merits of trepanning against gamma ray or radiography. In favour of gamma ray there is the non-destructive criticism of the joint, but should a trepanning be taken from the joint, there is the replacement of a welded plug with

only the assumption that the plug is sound as it is not possible by observation to state definitely that a weld is good. The weld can have the appearance of being good but may be far from sound within the weld. Since the Standard Code offers little advice as regards weld quality, the responsibility rests upon the Surveyor and is largely a matter of personal opinion.

In fabrication, the "penetrating root run" technique is adopted and back deposition of weld metal is not encouraged except in special cases. The preparation for welding of a typical joint is illustrated in Fig. 13. Fig. 13A illustrates faults in preparation that lead to troublesome joints. Root runs must not show lack of root penetration or evidence of non-fusion exceeding $\frac{1}{16}$ in. deep nor exceeding $\frac{3}{8}$ in. long in any 3 in. length of joint. The limit of positive root penetration into the bore is $\frac{1}{8}$ in. up to 8 in. dia. or $\frac{5}{16}$ in. over 8 in. dia.

It is extremely difficult for the Surveyor in attendance on this type of work to be present at all the various stages of manufacture; some of these may even be carried out simultaneously within the same department. The authors have found that it is most important for firms engaged in this work to maintain adequate supervisory and inspection departments. These departments are responsible for the quality and technique of the work when passing through the shops and in case of doubt should consult the Surveyor. Where marked deviation from the proposed procedure is evident, the responsibility rests with the Surveyor who may choose to discuss difficulties with the Customer, should this be necessary.

TUBE DEFECTS

Before dealing with inspection requirements, it might be advisable to enumerate the more common defects likely to be encountered in tubes. Defects are traceable either to the material used or to the methods adopted in each process.

Laminations

These are found more often in the weldless tubes than in the welded type.

This is understandable in view of the considerable material displacement which takes place in either the static or rotary piercing method of changing a solid bar or billet into a hollow, and ultimately a tube (Fig. 14). Should there be a segregation in the bar or billet at either the centre or towards the surface this will be elongated and emphasized in the tube, and will be found as internal or external laminations. In cases of external laminations these may clean up by light grinding, but if a thin black line remains, then it is certain that the lamination goes much deeper. The detection of a lamination internally is much more difficult and recognition of laminations inside a tube can only be acquired by experience. When laminations in the inside wall of a tube are detected, the tube should be sectioned at that point when a close-up of the lamination can be made and useful data obtained. In the push and draw bench processes, whilst laminations occur, as in the other processes, they do not often come within the inspector's range as the working of these tubes normally shows them up effectively before the operations are complete and they are therefore discarded before they reach the inspection stage. In the welded processes laminations will only be apparent if present in the plate before shaping.

Surface imperfections may be caused in any of the rolled processes. Scale, if adequate precautions are not taken, can be rolled into the outer surface of the tube when passing through the mill. On occasion the rolls themselves pick up foreign matter which may adhere to the roll surface and impart a blemished finish to the tube. It is necessary, therefore, that frequent examination of the rolls takes place and if evidence of wear or that they have become misshapen, is present, the roll-set should be changed.

Eccentric Walls

Variations in wall thickness of the finished tube are generally caused by being present in the hollow bloom itself. In the 'Pilgered' tube, however, it can sometimes be caused by the process itself either by a cold spot on the billet or a bent mandrel.

Double Wall or Lamination

Again this is a defect which is present in the rolled bar or ingot and may be segregations or "piping" which become emphasised in the piercing and elongating processing of the solid into a hollow (Fig. 14A). The further elongating and thinning stretches the affected zone and when the discard takes place it is insufficient to eliminate the defect.

Ovality

It is not usual for the tube to be out of round after the rolling process, but at the sizing and straightening roll operation, unless care is taken, ovality may be effected by "spread" of the rolls This can be minimised greatly by care in the rotation of the tube at each pass through the sizing mills.

INSPECTION

As the Society is covering the inspection duties of pipework for several oil concerns it may be of service to Surveyors if a few suggestions be made here regarding requirements of inspection.

The tube mills are usually of two kinds, i.e. stock mill or line mill.

A stock mill is one which, no matter what the process employed, makes a great variety of sizes and has the room and facilities to stock its sizes up to a reasonable quantity. A line mill on the other hand, when operating on a particular size of tube, produces as much as possible of this size in accordance with the orders held, and must have these inspected and cleared during the time of manufacture.

When inspection is at a stock mill, it is the usual practice for the manufacturers to request the attendance of a Surveyor when required and various sizes and qualities might be submitted. Checking of the material by physical tests in accordance with the specification is the primary step, then the certification by the mill of the chemical properties of the material by the ladle analysis, the identification of the cast, and a check chemical test if required. Next, the examination of the tubes, checking of wall thickness, external and internal surfaces, length, if finished size is given and the taking of hardness tests, if the tubes have to be expanded into tube plates, etc., and concentricity of the tubes. If the tubes are for the manufacture of butt welding fittings it is necessary to see that the cast number from which the tubes came, is steel stamped on each tube, and the testing by hydraulic pressure to the approved poundage per square inch. If the tubes have bevel-ends, bevels and lands should also be checked and particular attention paid to the land or root face dimension. The bevelled face should be smooth. Knurled effect created by chattering of the tool, etc., should be discouraged.

Line Mill

The procedure is the same except that hydraulic testing is carried out prior to inspection of the tubes, and as can be understood, it would not be possible to witness every tube being tested and at the same time carry out the examination and checking of the tubes as they pass over the inspection benches. It should, therefore, be the object of the Surveyor and manufacturer to have the final inspection benches as near as possible to the hydraulic pump, when from time to time the Surveyor can witness the hydrostatic test being carried out and be able to check on the time that pressure is being maintained. The percentage of testing thus witnessed could be, say, 10% and the manufacturer could then furnish a certificate or an assurance that the balance has been similarly tested.

Plain End Tubes

No matter for what purposes plain end tubes are to be used, the fundamental principles of inspection remain unchanged. Firstly, the requirements of the order should be ascertained and secondly, tubes should be selected, identified and stamped for the physical tests required. After the tests have been witnessed and found satisfactory, the examination of the tubes is carried out and should cover the following points :—Wall thickness, diameters, concentricity of bore, concentricity of outside circumference, the internal and external surfaces, and the ends for lamination, and hydraulic tests of a selected percentage. It is the general experience of Surveyors that the creating of shock by striking sharply with a hand hammer while pressure is sustained is rarely carried out by the manufacturers unless insisted upon, and Surveyors should pay attention to this point. Where definite lengths of tubes are specified the tolerance should not exceed $+ \frac{1}{8}$ in.

Screwed Ends & Couplings

For the oil industry screwed end tube is usually for either well casing, tubing, drill pipe or line pipe, and each of these have their own special requirements and the first step of inspection, therefore, is to become acquainted with these requirements. This can only be done by reference to the customers' order, and the specification mentioned thereon. Drill pipe is not dealt with much in the Authors' area, but its

importance is obvious when one considers the duty imposed on it in carrying a drill bit through geological strata in the drilling of a deep well.

Tubing

Tubing which may be of plain or upset ends, either external or internal, is important, as it is the first string of tube following the drill and through which the sludge is pumped. If the tubing is upset (i.e. thickened back on itself) either externally or internally, it is for use in deep wells, and the importance of the thread form, taper, and pitch being of high quality can be appreciated when the weight suspended on the coupled lengths is visualised. Another important feature is in the quality of the upset itself. The method of forging these ends is given in the section headed "Upsetting, rounding operations, etc." Cavities may occur when the tube is forced back on itself for a controlled distance, owing to eccentric wall thickness or if the die blocks on the staver give slightly under the pressure imposed on them. These cavities must be looked for in the bore of the tube at each end, and, if present, the tube should be rejected.

Non-upset tubing is, as the name implies, plain tubing of the same quality of material as used for upset and is of the same wall thickness throughout. In this type the number of threads is increased but the same standards of tolerances apply.

Casing

As has already been stated, casing is the oil well lining, and as in the drill pipe and tubing, it is very important that the material quality and the workmanship be of a high standard. In most oil wells, except for very shallow wells, the threads of tube ends and couplings are of the 'U' form, i.e. round, top and bottom, and are of given taper. The requirements of these threads are fully dealt with in the A.P.I. Specification 5A and the instruments for measuring and the tolerances allowed, are discussed and illustrated in 5B. Before inspecting any of the tubes required for a well "string", Surveyors should make themselves fully acquainted with the aforementioned specifications. The material for the foregoing is of a quality indicated by the following symbols, F.25, H40, J55 and N.80 etc. and the numeral of each type is indicative of the yield strength of the material, viz., H40, 40,000 lb. yield strength minimum. The length of tube is given by Range 1, Range 2 or Range 3 and covers the lengths 18 ft. to 40 ft. A feature of the inspection of these tubes is that each tube must have a drift plug of the bore size less stated tolerances passed through it for its entire length, and after screwing and the wrenching on of the coupling, a further drift test should be witnessed on each one, the drift in this case passing into the tube for a distance beyond the screwing zone. Couplings should also be measured before and after electro zincing or galvanising and the thread form checked.

LINEPIPE

The requirements of linepipe are fully covered in the A.P.I. Specification 5L and this specification deals with plain ends, bevelled ends and screwed and socketed pipes. In threaded linepipe the thread is of the 'V' type or sharp top and bottom and is also cut on a taper. The instruments for measuring casing, threads, etc., are also used for linepipe but differently shaped points are fitted.

The examination of all tubes, after ascertaining the specification and order requirements, is routine. Billets from the steel works are marked with the cast number and these are recorded, placed in the furnace in such a fashion that as they move to the mill the record is received at the Checker's Office which controls the hot saw. As the tubes are cut to length they are passed to the sizing rolls and the cast number, thickness, etc., painted on with an indication as to which end of the tube passed through the mill first. It should be the first step of the inspection to check this procedure.

In the inspection of tube forgings, i.e. butt welding ells, tees, crosses, etc., again it is necessary to be familiar with the requirements of order and specification. The buttwelding fittings can be either fabricated or forged. For low pressure water services 45°, 90° or 180° tube turns may be made of segments welded together. For higher pressure and temperature work, pressed plate, made in two halves and welded along the throat and back seams can be used or they can be forged by the processes already described. In either cases, apart from the weld examination, these fittings must be checked for wall thickness entirely, and Surveyors may often have to devise ways and means of checking thickness throughout the complete wall of the fitting. Fittings must be checked on ends for

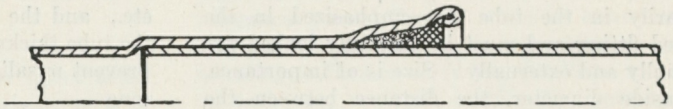
squareness of the end face in relation to the other faces, also to the plane of the fitting, and for angularity and twist. Surface defects if present primarily in the tube are emphasized in the finished fitting and must be carefully looked for internally and externally. Size is of importance, i.e. inside diameter, the distance between the faces, the outside diameter and the roundness of the welding joints because of the matching up with tubes and flanges. Tube thicknesses are given by schedule numbers, i.e. schedule 30-40, etc., and the matching of the fittings' ends with the tube thicknesses indicated must be accurate to prevent misalignment of the bores at the welding zone.

CONCLUSION

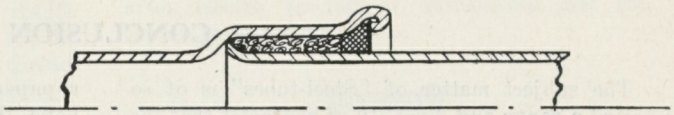
The subject matter of "Steel-tubes" is of so varied a range and diversity of character that the authors feel it cannot be adequately covered by a paper, but they offer this effort in the sincere hope that it may at least be found of some interest to colleagues of the Staff Association.

TABLE 1

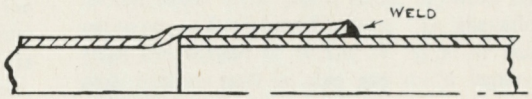
LONG SLEEVE INSERTED JOINT
FOR LEAD & YARN PACKING



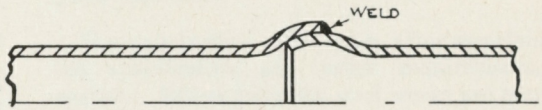
INSERTED JOINT
FOR LEAD & YARN PACKING



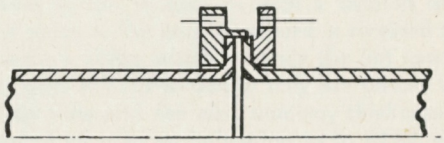
SLEEVE — FOR WELD



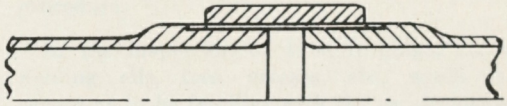
SPHERICAL END FOR WELD
ALIGNMENT



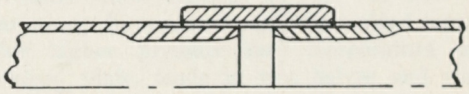
LOOSE FLANGE JOINT



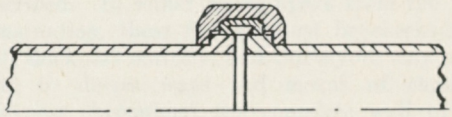
EXTERNAL UPSET



INTERNAL UPSET



VICTAULIC JOINT



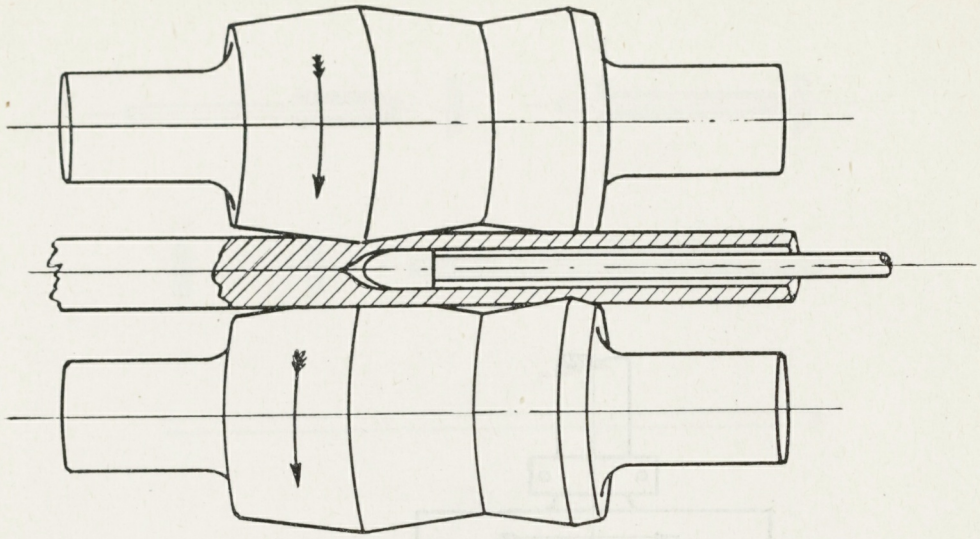


FIG. 1

MANNESMAN PIERCING ROLLS

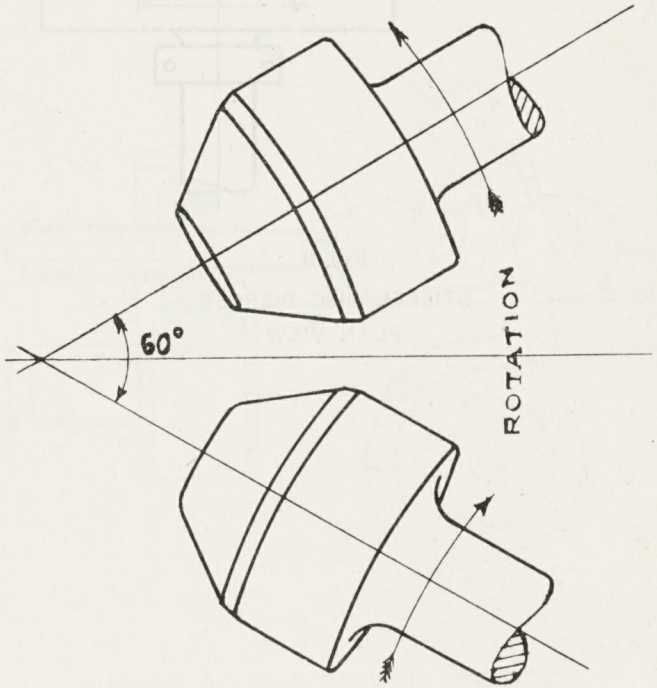


FIG. 2

STIEFEL CONICAL

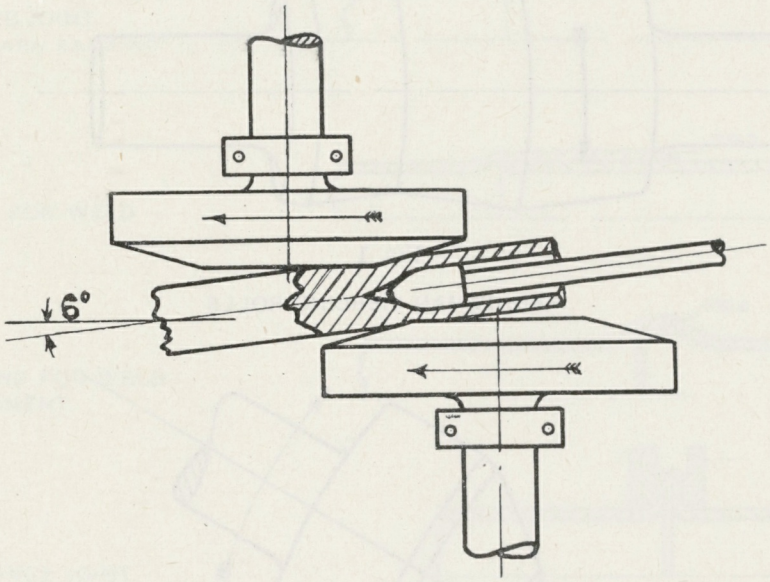


FIG. 3

STIEFEL DISC PIERCER

PLAN VIEW

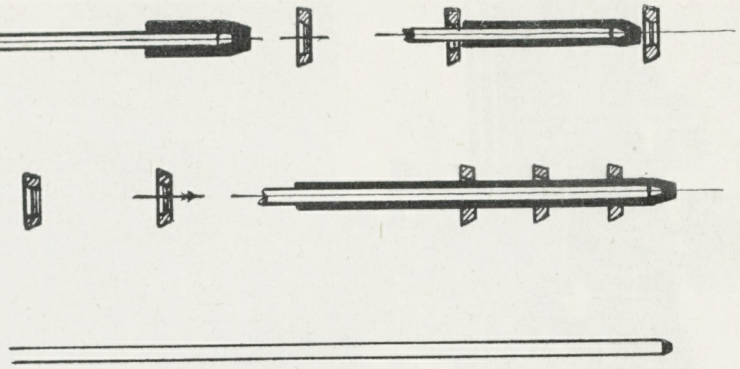


FIG. 4

PUSH BENCH

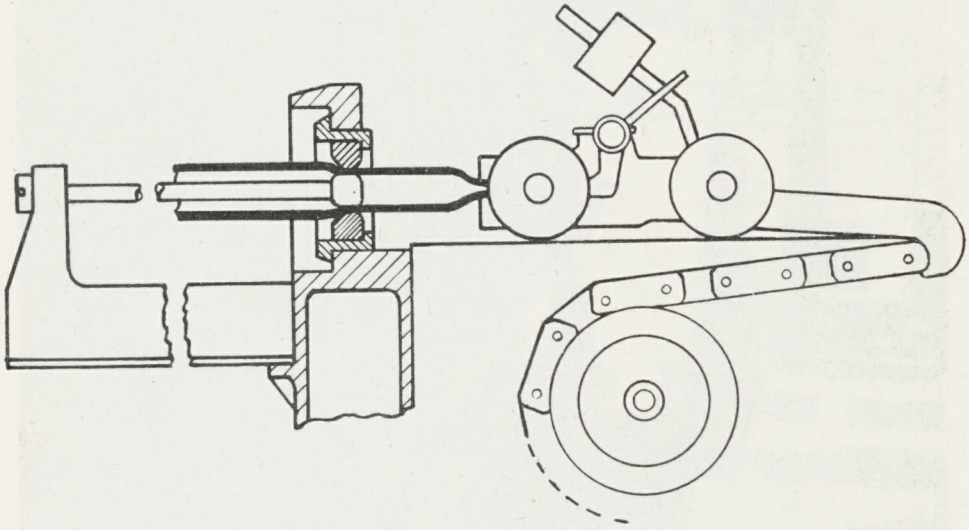


FIG. 4a

DIAGRAM OF COLD DRAWING OPERATION

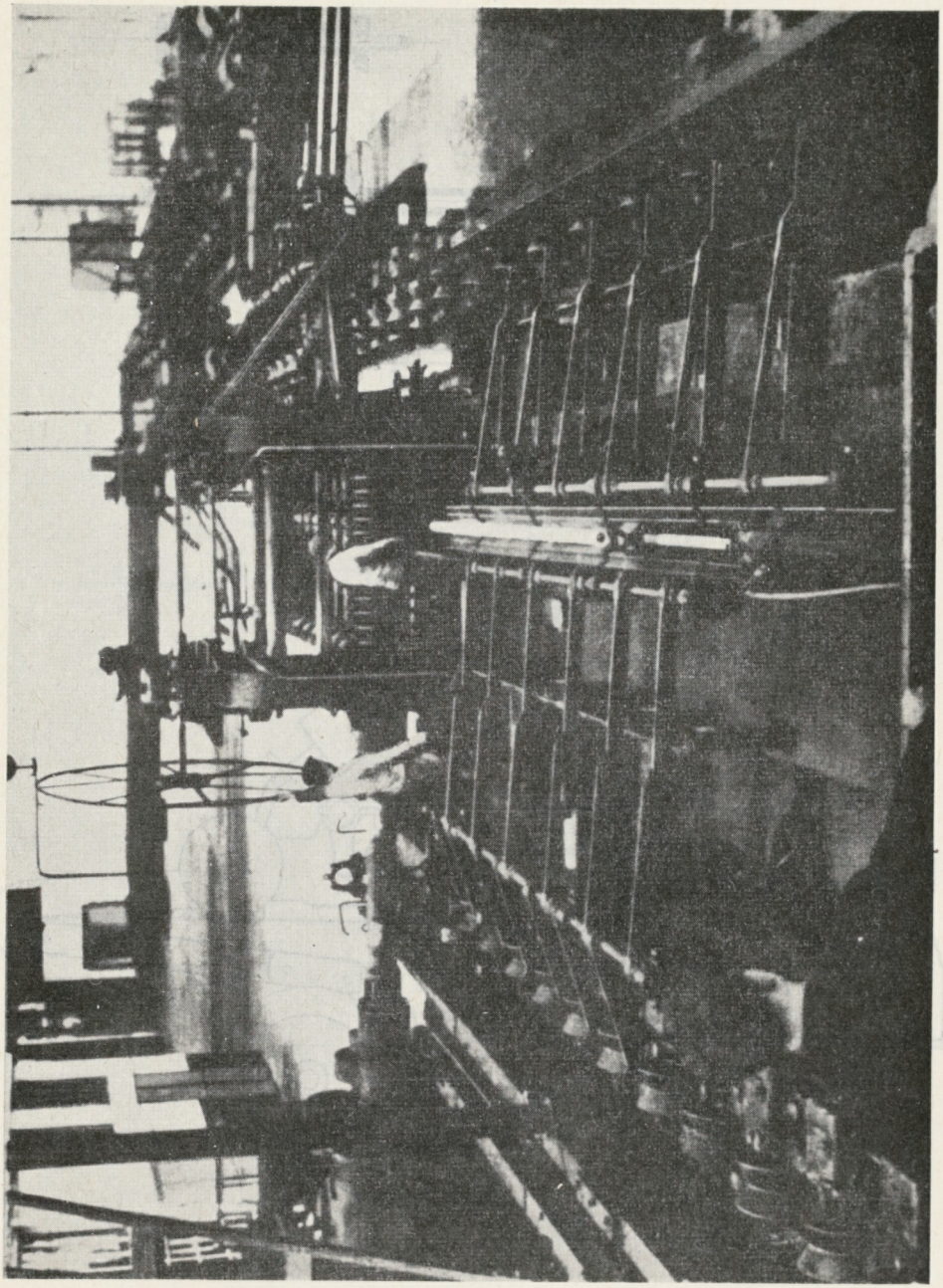


FIG. 5

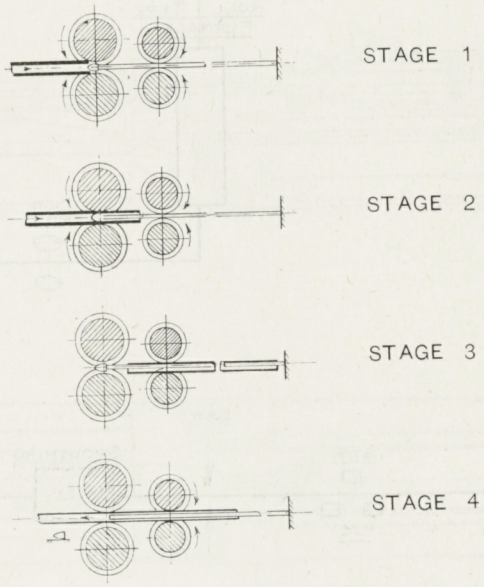


FIG. 5a

PLUG MILL ROLLING EFFECT

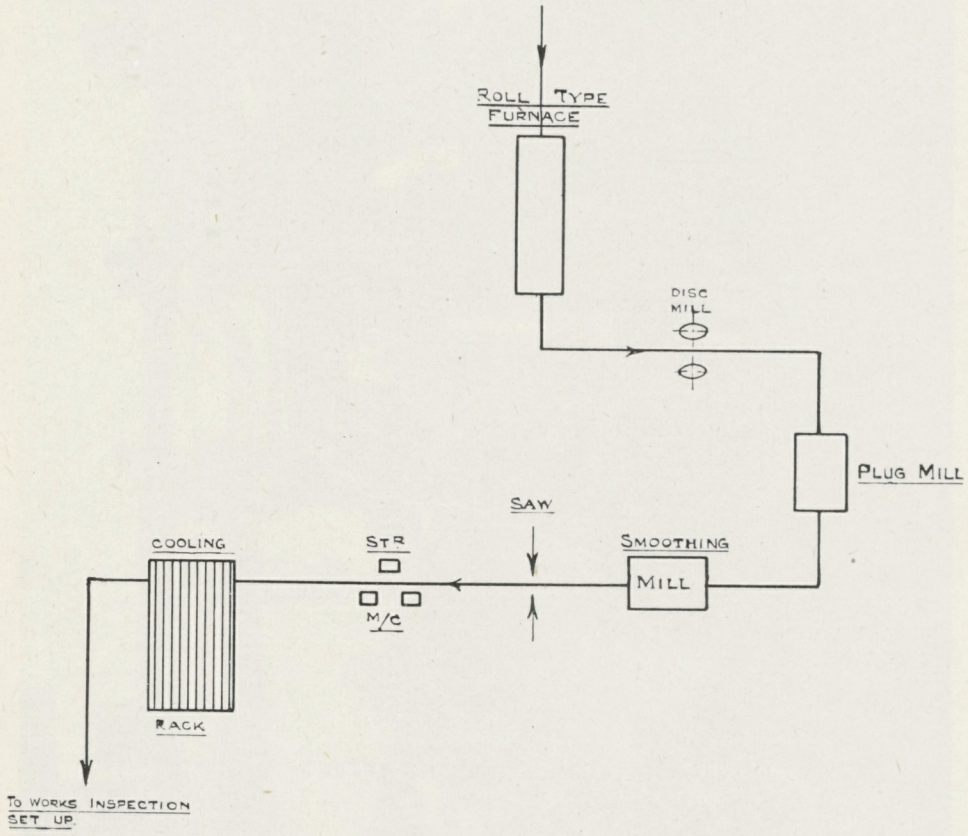

ROLL TYPE
FURNACE
DISC
MILL
PLUG MILL
SAW
COOLING
STR
SMOOTHING
MILL
M/C
RACK
TO WORKS INSPECTION
SET UP

FIG. 5b

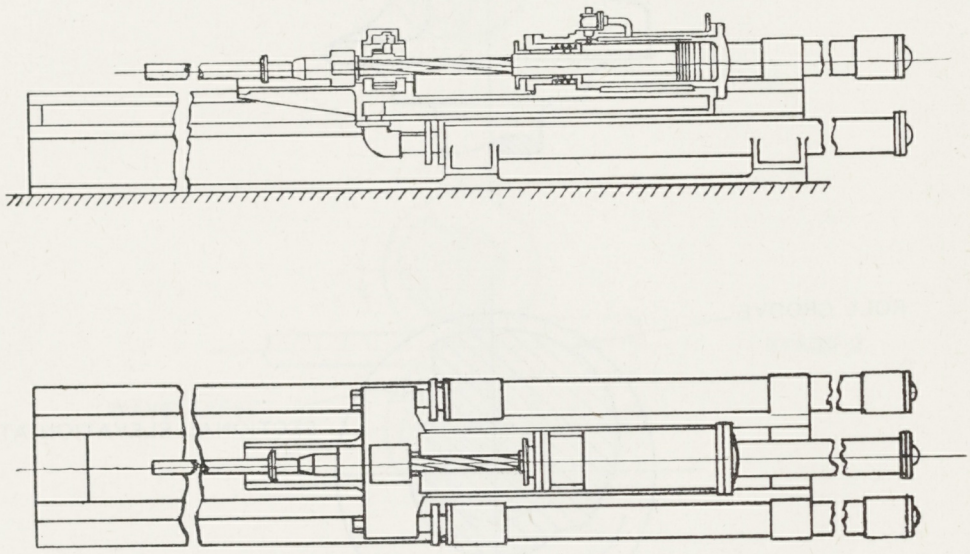


FIG. 6

PILGER FEED MECHANISM

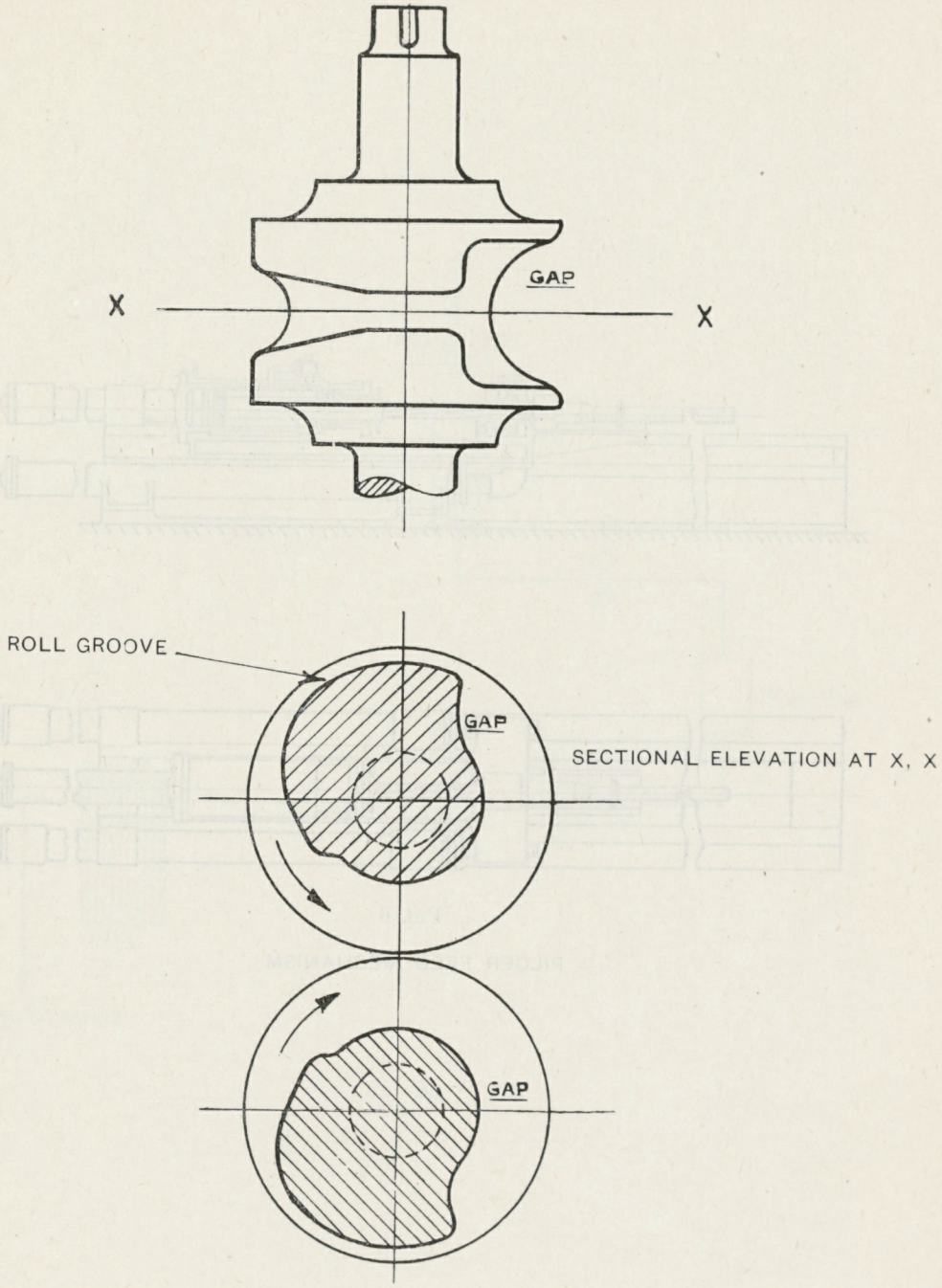


FIG. 6a

PILGER ROLLS

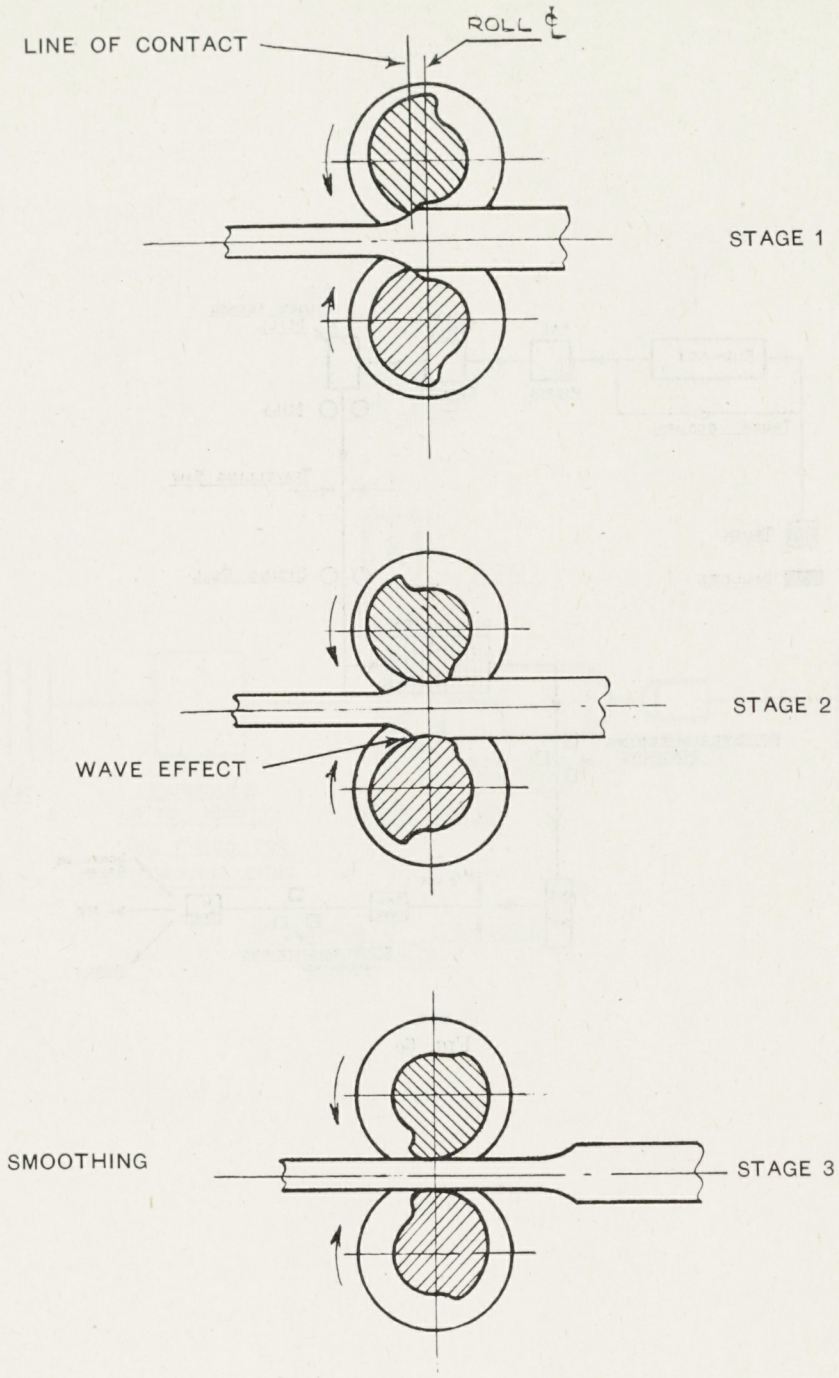

LINE OF CONTACT
ROLL ℄
STAGE 1
STAGE 2
WAVE EFFECT
SMOOTHING
STAGE 3

Fig. 6b

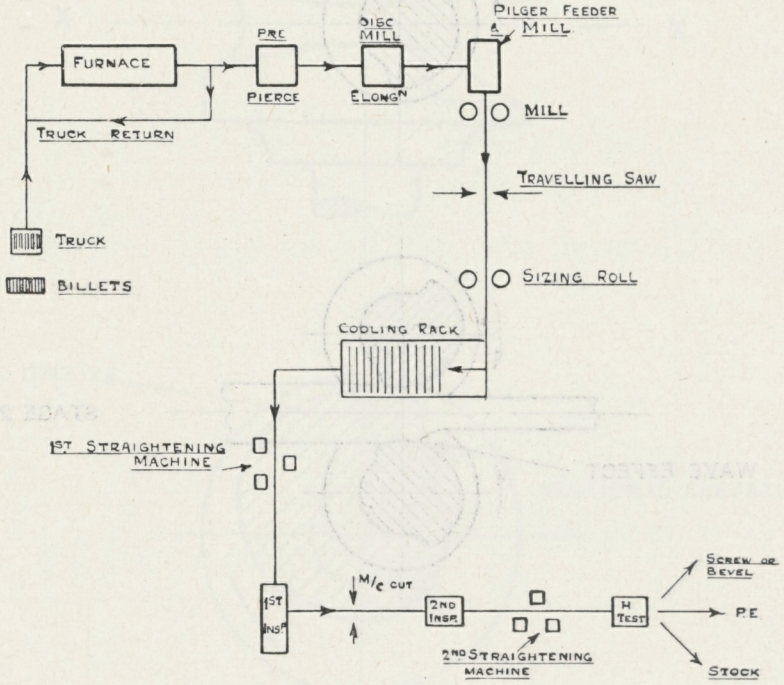

FURNACE
PRE
PIERCE
DISC MILL
ELONGN
PILGER FEEDER & MILL
MILL
TRUCK RETURN
TRAVELLING SAW
TRUCK
BILLETS
SIZING ROLL
CODLING RACK
1ST STRAIGHTENING MACHINE
M/C CUT
1ST INSP
2ND INSP
H TEST
SCREW OR BEVEL
P.E
STOCK
2ND STRAIGHTENING MACHINE

FIG. 6c

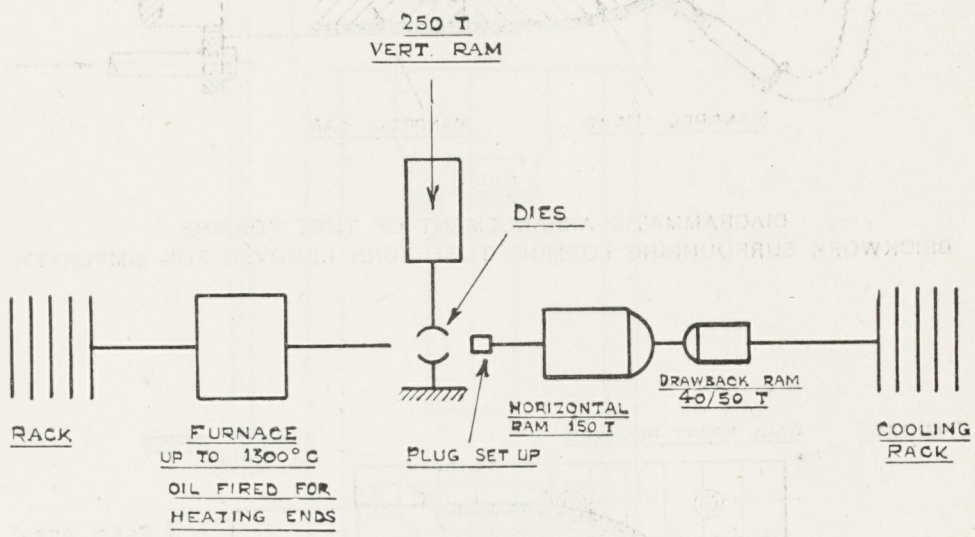

250 T
VERT. RAM
DIES
RACK
FURNACE
UP TO 1300° C
OIL FIRED FOR
HEATING ENDS
PLUG SET UP
HORIZONTAL
RAM 150 T
DRAWBACK RAM
40/50 T
COOLING
RACK
HYDRAULIC CONTROL
THROUGHOUT

FIG. 7

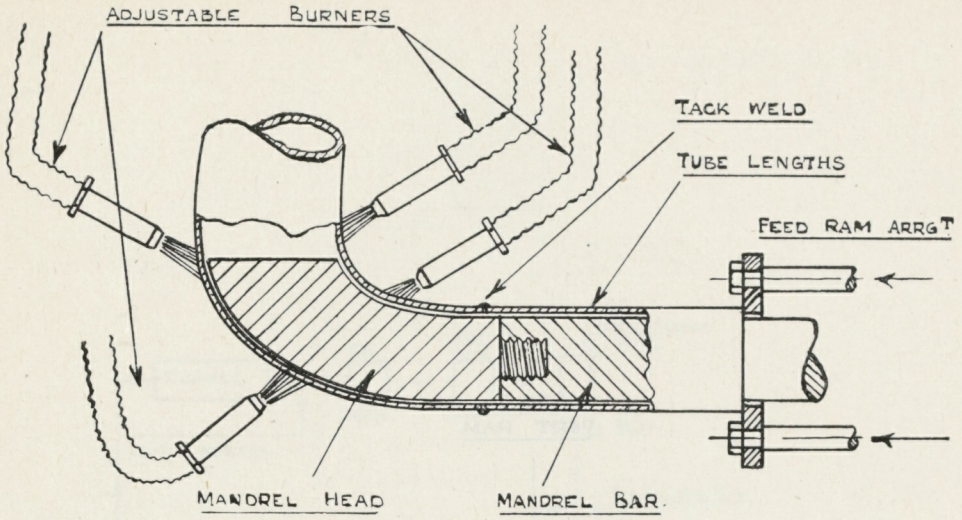


FIG. 8

DIAGRAMMATIC ARRANGEMENT OF TUBE FORGING.
BRICKWORK SURROUNDING FORMING TUBE TURN REMOVED FOR SIMPLICITY

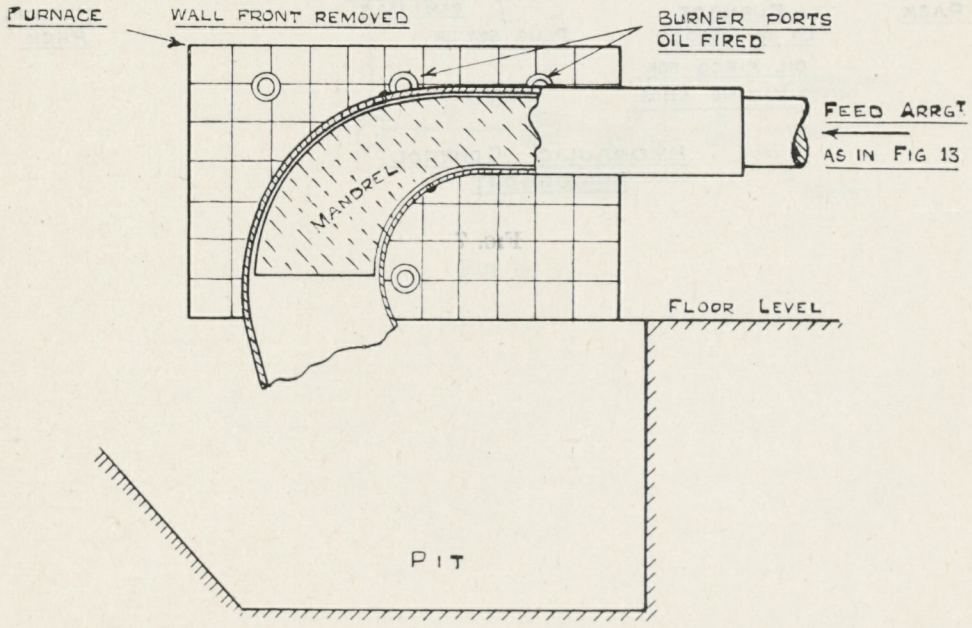


FIG. 9

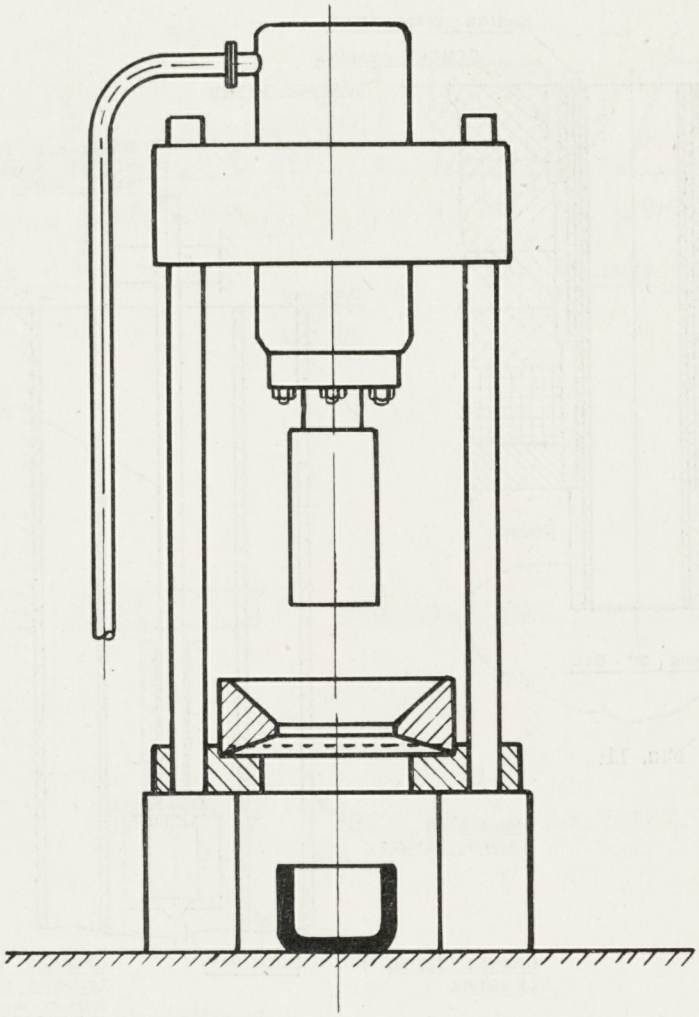


FIG. 10

EHRHARDT HYD. DRAWING PRESS

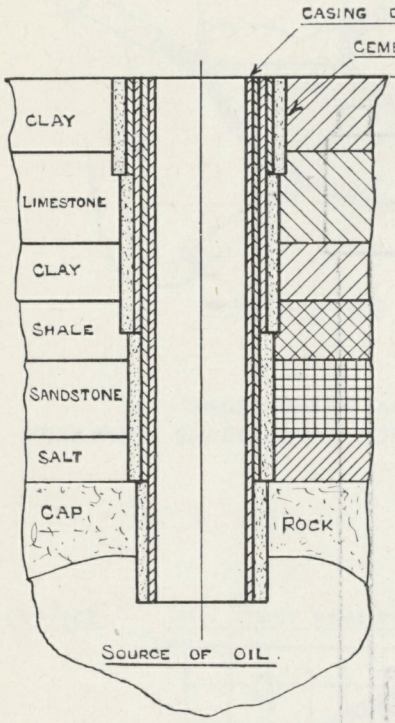

CASING DIAMETERS
CEMENT SEALING
SURFACE LEVEL
CLAY
LIMESTONE
CLAY
SHALE
SANDSTONE
SALT
CAP
ROCK
SOURCE OF OIL.

FIG. 11.

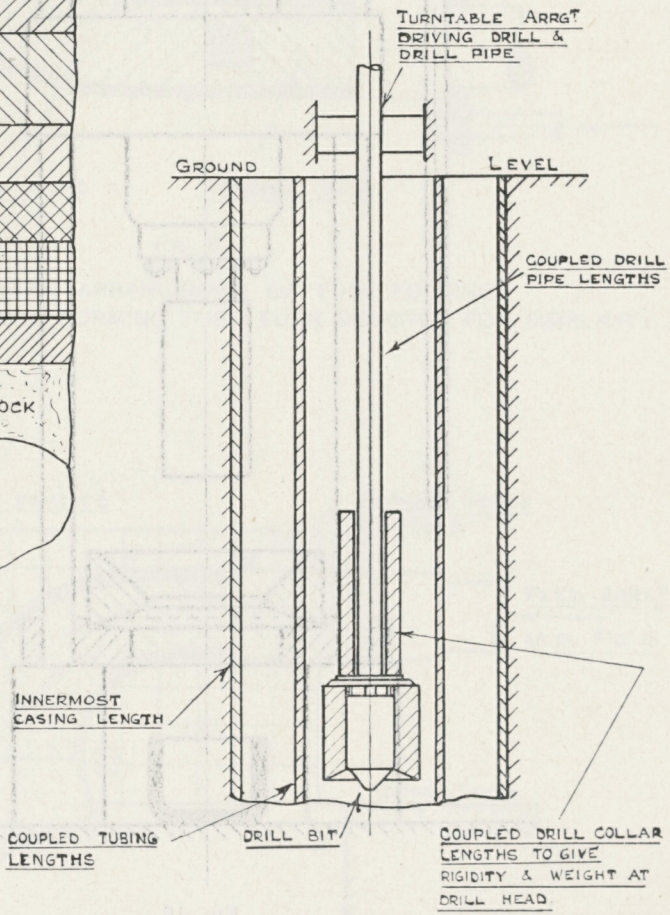

TURNTABLE ARRGT DRIVING DRILL & DRILL PIPE
GROUND LEVEL
COUPLED DRILL PIPE LENGTHS
INNERMOST CASING LENGTH
COUPLED TUBING LENGTHS
DRILL BIT
COUPLED DRILL COLLAR LENGTHS TO GIVE RIGIDITY & WEIGHT AT DRILL HEAD

FIG. 12

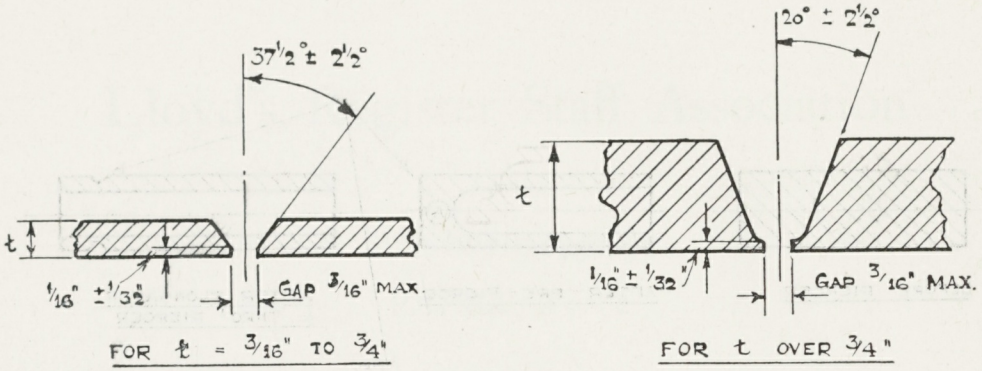


FIG. 13

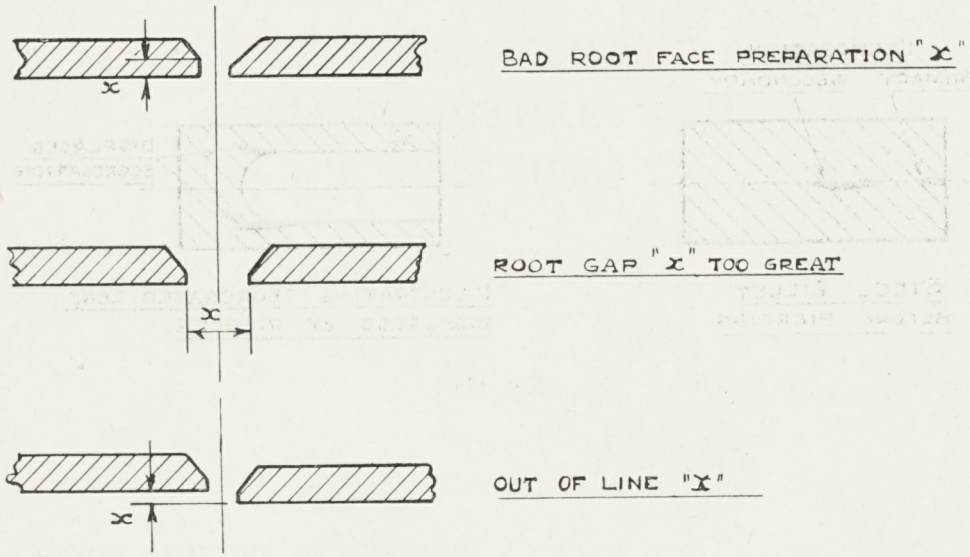


FIG. 13a

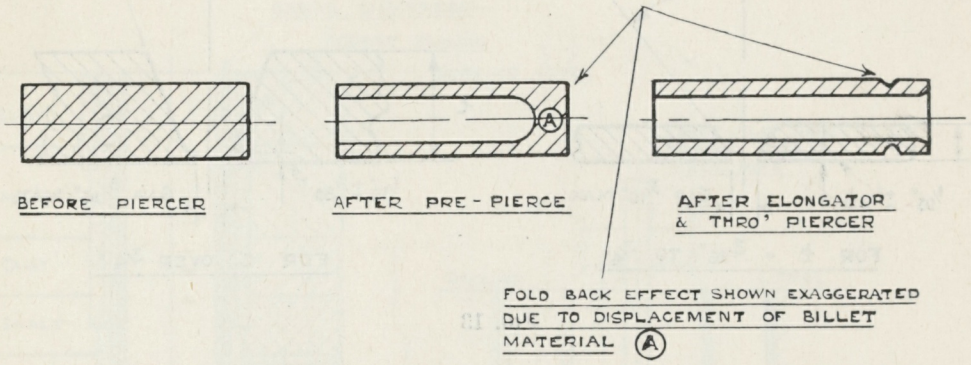

BEFORE PIERCER
AFTER PRE-PIERCE
AFTER ELONGATOR & THRO' PIERCER
FOLD BACK EFFECT SHOWN EXAGGERATED DUE TO DISPLACEMENT OF BILLET MATERIAL (A)

FIG. 14

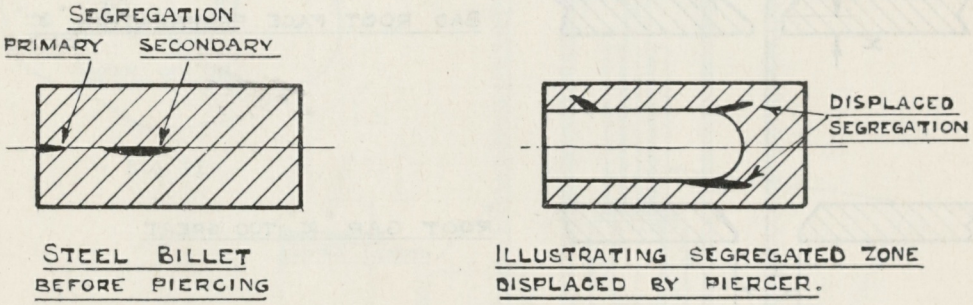


FIG. 14a

PRINTED BY LLOYD'S REGISTER OF SHIPPING AT THE SOCIETY'S PRINTING HOUSE, 64, SOUTHWARK STREET, LONDON, S.E.1, ENGLAND.
NOVEMBER, 1952.

PRIVATE AND CONFIDENTIAL

Lloyd's Register Staff Association

SESSION 1952-53

PAPER No. 2

DISCUSSION

on

Mr. F. Campbell's and Mr. G. McFarlane's Paper

STEEL TUBES: MANUFACTURE AND SOME USES

LLOYD'S REGISTER OF SHIPPING,

71, FENCHURCH STREET,

LONDON, E.C.3

The Authors of this paper retain the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals

Discussion on Mr. F. Campbell's and Mr. G. McFarlane's Paper

STEEL TUBES: MANUFACTURE AND SOME USES

J. CRAWFORD

I would like to thank the Authors for their comprehensive and interesting paper and congratulate them on getting down to detail on such a wide subject.

There are one or two points I would like to mention, where a difference of experience might be worth recording.

(1) Under "Manufacture" the limit on weldability of steel laid down by the paper is considerably less than exists in modern practice, and instead of 0·18 per cent Carbon and 28–32 ton tensile, it is common practice to use Carbon from 0·04 to 0·35 per cent giving a tensile variation of from under 20 to over 40 tons per square inch tensile strength.

(2) As an old Surveyor most of my experience has been with the manufacture of lap welded wrought-iron tubes, but now both these and the butt welded tubes as described in the paper form a very small proportion of the welded tube tonnage produced in this country.

By far the greatest tonnage of commercial gas list tubes is supplied by the Continuous Weld Process, and in sizes not only up to $2\frac{1}{2}$ in. diameter, but ranging from $\frac{1}{4}$ in. to 4 in. nominal bore. The quality of this weld is now such that for many purposes it has displaced seamless tube.

The speed of welding has increased considerably, and when I visited a modern tube works in September last, one of the mills was operating at between 7 and 8 ft. per second, but even this is slow when compared with the latest American practice of 16 ft. per second.

Mention might also be made of a technique known as welding-cum-reducing, in operation on the C.W. mills, whereby the tube, after welding, is stretched by up to twelve passes to produce a $\frac{1}{2}$ in. tube from what was formerly 1 in. bore strip.

(3) Electric resistance welding as I have seen it is slightly different from the description given by the Authors and, as this process is now providing a large number of boiler tubes to Lloyd's requirements, a remark on what I saw may not come amiss.

Mechanical scalebreaking, pickling and cold rolling are all essential features of the strip preparation, to ensure accurate dimensional control prior to the strip being fed to the welding mill. At the latter, the edges are not planed as suggested, but a definite amount is slit off by slitter blades so that the width of strip is accurately determined as well as the thickness from the cold roll mill.

The strip-forming mill, fin pass rolls and seam guide rolls all contribute to shaping the strip to the correct form for welding, the weld itself being effected by a combination of heat and pressure without any extraneous additions. The heat is generated in the edges of the close-formed tube by the passage of a high frequency current flowing from two large copper disc electrodes insulated from each other and running freely on the top of the tube. The pressure is induced partly by the electrode pressure but mostly from the action of two squeeze rolls bearing on more than two-thirds of the tube circumference. The result is a completely homogeneous weld with excess metal squeezed out on both the inner and outer surfaces of the tube for removal later.

(4) Another feature which might be mentioned is the hot reducing mill. This equipment is associated with almost all small size seamless plants to enable the manufacturer to ring the changes in size and gauge without carrying a variety of tools and rolls for the main producing unit, be it automatic mill or push bench. There are many varieties of design of these mills from the Standard American 2-roll pass, to the British and Italian 3-or 4-roll passes. A

reduction of 2 to 3 millimetres per pass is considered good practice. The thickness of the tubes is controlled by the tension on the tube between the set of rolls. This counteracts the tendency of the tube to thicken as the tube area is reduced.

J. McKEOWN

While is is appreciated that the scope of this paper precludes a thorough technical survey of all the aspects of tubing, I would, however, like to draw the attention of the Authors of this fine paper to the direction through which the rolls of the Mannesmann mill is shown to rotate.

This appears to be incorrect, as the angularity and direction of rotation would tend to resist the passage of the billet through the rolls. As this error in conjunction with the Authors' remarks regarding singularity in regard to direction of rotation would tend to prevent a full understanding of the cavitation by Surveyors not in contact with this type of mill, a wider explanation of this system should not be out of place.

The billet is entered between the rotating rolls and compressed at two points which are continually changing, but which are always in diametrically opposite sides of the centre, so that during the slow longitudinal travel through the first few inches of the rolls, a flaw forms in the centre of the billet, which flaw it is the function of the remainder of the rolls to enlarge.

This flaw is caused by the outer layers of the bar offering more resistance to compression than the latter centre offers to tension, the particles near the centre being stretched at 90 degrees to the direction of compression, and if the strain is repeated often enough as in a rotating billet enlargement or cavitation of the flaw occurs.

This enlargement is further due to the fact that the farther ends of the rolls are larger in diameter than the end at which the billet enters, and their surfaces travelling faster twist the outer portions of the billet round circumferentially more rapidly than the smaller ends will permit the outer surface at their end to revolve; and as the axes of the rolls are not parallel to that of the bar, but are inclined to it, they, at the same time, pull forward the outer skin of the bar longitudinally, drawing out and twisting the surface in a spiral direction.

As the bar does not decrease in diameter as fast as it increases in length (this decrease is not shown in sketch) metal must be withdrawn from somewhere, and the place from which it is drawn is the centre of the bar, enlarging the flaw already formed, and converting the solid billet into a hollow tube, the bore of which is further enlarged and smoothed by the mandril.

W. C. COWIN

Do the Authors know if electronic measuring devices are being used to determine thicknesses of pipes ?

A. OZOLS

The paper gives much useful information to a Surveyor, who has to test and examine tubes for different purposes. It gives an elementary knowledge as regards various processes applied to the manufacture of tubes. It emphasises the principal differences as regards requirements for the quality of material for a welded tube in comparison to a solid drawn one—weldability limiting physical properties of the material. Commonly this point is omitted which places solid drawn tubes in a more favourable light.

As long as a Ship and Engineer Surveyor has to deal with boiler tubes, he feels fairly confident on the job. Not so when tubes for oil industries are to be examined and tested. A country rich in good ore and steel industries cannot expect also to have oil deposits and industries based on oil. The paper gives short descriptions and sketches regarding use of tubes in oil wells and lines and so brings the tube Surveyor more into contact with reality.

I have to thank the Authors for their paper and I am convinced that many colleagues will agree with me in this.

Regarding that part of the paper dealing with defects and examinations of tubes, I had expected more advice from the Authors.

Having seen the piercing of the billet, its elongation into a hollow bloom by the Mannesmann Process, then rolling and drawing it to say a 2 in. tube of about 10 metres in length, one is entitled to have some doubts as to whether the thickness of the tube wall throughout its whole length lies between the thicknesses found at the tube ends. I remember having read somewhere that the mandrel, by some laws of elementary physics, keeps always to the very

centre of the billet. If so, how is one to explain the difference in wall thickness found at the ends, and the eccentricity? Do these differences occur in the piercing or are they caused later in the rolling or drawing?

The forces upon the material at the piercing and feeding of the billet towards the mandrel are of such a character, that to understand the whole process and its results by means of simple reasoning is rather difficult. It seems clear, however, that a bent or defective mandrel causes eccentricity, but is a mandrel of absolute correct form and clean surface a guarantee for a concentric tube, within limits of permissible tolerances, for the whole of its length? Or are there some other methods of keeping the process under control in order to ensure concentric tubes for the whole of the length. An answer to these vital questions from a young Surveyor's point of view, by experienced colleagues, will be much appreciated.

"In cases of external laminations these may be cleaned up by light grinding", we read in the paper. Usually this cleaning up is done before the tubes are submitted for the Surveyor's inspection. If it is done by an experienced workman, the tube, after grinding, is so well rounded up and the surface dressed, that it is not possible to judge the thickness of material actually ground off. In such cases tube diameter is checked for the "cleaned up" length and, if found between the tolerances, the tube is usually accepted. Simple calculations will show that such control does not disclose wall thickness, which might be ground considerably below the limits. This may prove especially so if, by accident, the laminated and cleaned up place coincides with eccentricity on the side of the thinner wall. What should one do to be on the safe side?

A Ship Surveyor would perhaps hammer test the tube for unduly thin walls or ask to drill a test hole. The first does not work, the second makes the tube defective. It would help the Surveyor to form his opinion with more confidence if the laminations were left as found and the grinding off were done in his presence. This seems impracticable as time spent on examination would increase considerably. Some French Rules provide for cutting of 2 per cent of tubes submitted for examination at their middle length to ascertain the thickness. A stipulation in the Rules giving the Surveyor the right to ask for the cutting of a tube whenever deemed necessary, would be of great help. Comments on this question would be helpful.

The value of looking for defects on the internal surface of a 10 metre long tube lighted by a lamp from the other end has always seemed to me more or less problematic. I have done it, however, just in the hope of discovering some inside lamination close to the ends. The sentence in the paper, that recognition of laminations inside a tube can only be acquired by experience, is a very provocative one. Humanity has learned by experience and passes all its knowledge on from generation to generation by means of putting it down in writing. Cannot also this experience be submitted to paper and made available to less experienced Surveyors? The Authors are kindly requested to do so and give at least some useful hints on how to approach this problem.

Scars in hot rolled tubes are easily visible defects on the internal surfaces. For a tube to be used as a pipe (for internal pressure) these scars are to be regarded as "cuts in" or "breaks" and may cause a locally "weak point". A kind of workable tolerance given for dealing with these defects would also be appreciated.

Maybe the questions raised by me in connection with the paper are rather theoretical and nothing much to an experienced inspector. Perhaps I myself may think so after some years' more experience. Anyhow, the answers would help considerably a young Surveyor starting work and therefore be of value.

The usual clauses "good, so far as seen" or "free from visible defects" will still remain. But to try to reduce the scope covered by such clauses is sound and, in my opinion, this entitles a young Surveyor to ask questions.

AUTHOR'S REPLY

To Mr. Crawford

The Authors appreciated Mr. J. Crawford's contribution to paper No. 2 and are indeed indebted to him for his very helpful remarks and his elaboration of the C.W. Process as carried out at Corby; also his remarks on welding-cum-reducing and on hot reducing mills. It was not claimed by the Authors that all the processes, both fundamental and supplementary, had been adequately covered by the paper, but that the principles of tube making might be a little clearer to some of their colleagues.

However, in paragraph one of Mr. Crawford's remarks he states that the limit on weldability of steel laid down by the paper is considerably less than exists in modern practice. He further states that it is common practice to use carbon from 0·04 to 0·35 per cent. It should be appreciated, however, that the statement in the paper was that for furnace welded tubes, weldability of the steel was of fundamental importance and that steels used for this purpose must have a relatively narrow range of composition. This statement is still adhered to by the Authors and while admitting that in certain plants, i.e., the continuous weld process, high tensile tubes are butt welded, it could scarcely be said to be common practice. In this country there is a large proportion of the manufactured tubes lap welded and butt welded and the range of composition is essentially between 0·18 and 0·23 per cent. The information that the speed of welding on the continuous welding is now 7–8 ft. per second in this country is of great interest and the Authors' thanks are due to Mr. Crawford.

Mr. Crawford's detailed remarks regarding the cutting of E.R.W. tubes to exact width by slitter blades instead of planing are noted with interest.

To Mr. McKeown

Mr. McKeown in his contribution to this paper drew attention to the error in Fig. 1—Mannesman Piercing Rolls—and the Authors are indebted to him for his very able explanation of the principles of this method of producing a hollow cylinder from a solid billet. It should be stressed, however, that the piercing cone consists of the gradually tapering space between the working surfaces of the rolls through which the material passes spirally, the spiral motion being produced by the angled position of the axis of the rolls and the singularity of the rotation. The consequence of this movement is to make the material slightly elliptical on each rotation of the rolls and this is the reason of the cavitation.

The Authors would like to take this opportunity of thanking Mr. McKeown for his excellent contribution.

To Mr. Cowin

Mr. Cowin, in his reply to this paper, raised the question of the use of electronic measuring devices concerning tube thicknesses, but the Authors have been informed that no such device is in use at present on a commercial basis. It appears, however, that electronic measurements find an application as a research instrument, but its use is limited to tube sections of a very good surface finish. Since the principle involved is essentially that of a strong magnetic field, active between the contactors, it will readily be appreciated that any defect, such as grooving, scoring, etc., would impede the magnetic efficiency of the instrument. It is felt that such a method would prove the presence of a defect, but would not indicate its nature or magnitude.

The Authors have recently been informed that electronic measurement of tube thicknesses has been in use in America, but the Authors are not aware to what extent as far as tube mills are concerned.

Mr. Cowin is no doubt aware that the electronic technique for electro deposited metal upon magnetic basis has been in use in this country for some years, mainly in connection with chromium, nickel, copper and cadmium plating.

To Mr. Ozols

The Authors would like to thank Mr. Ozols for his encouraging remarks and in explanation of the points raised by him, the following comments are tendered.

Firstly, as far as the inspection of tubes is concerned, the Authors' main object was to emphasise the necessity of developing a procedure to be put into practice and which would be readily applicable according to the type of tube concerned and the specification requirements.

Secondly, to explain the difference in wall thickness found at the end of tubes and the eccentricity, the primary factor to be remembered is the method of manufacture adopted. The method of manufacture can be divided into two distinct classes:

(*a*) *The Pilger Process.*—The difference of wall thickness in this instance can be caused by a hot spot in the billet or hollow and during the forging process when the hollow is being turned through 90 degrees at each stroke of the feed, the lift of the mandrel bar in this soft spot causes a thick and thin wall. Experience has proved, however, that this thick and thin wall remains constant longitudinally throughout the length of the tube.

At this point, an interesting question arises as to whether a mandrel of absolutely correct form gives a guarantee of concentricity and the Authors are of the opinion that where, as pointed out above, the mandrel shows an affinity for the more plastic region of the material being worked, it is felt that by ascertaining good mandrel form at least one possible trouble spot is eliminated.

(*b*) *The Plug Mill.*—In this method of tube manufacture, the differences in wall thickness are most likely caused by the prepiercing of the billet. Here, the billet is partly drilled at its centre and is then fed through oblique rolls and over the mandrel, which is a plug fitted in the end of a bar of smaller diameter than the mandrel. The mandrel, which is held by the bar in the centre of the rolls, controls the cavitation of the billet caused by the oblique rolling process. It will be readily understood, therefore, that if the billet is truly centred the wall should be of equal thickness right round and throughout the length of the tube.

Mr. Ozols, in his contribution to the paper, also raised the question of cleaning up external laminations by light grinding and in reply to his suggestion that it would give a Surveyor more confidence to form an opinion if the laminations were left as found and the grinding off were done in his presence, the Authors are of the opinion that it is the first duty of the Surveyor to check the wall thickness at the end of the tubes. If the ground portion coincides with a wall thickness which is at the low limits of tolerance, then the Surveyor is in a position to check the amount ground off by the use of a straight edge applied longitudinally and measured by feelers and by a circumferential gauge curved to an arc of the circle of the circumference and measured again by feelers.

Regarding the sectioning of tubes, the Authors doubt whether the adoption of this process would be of very much help as each tube, no matter the process employed—apart from cold drawn, E.R.W., and C.W.—is individual and percentages sectioned would be no criterion that the remainder was correct. It is considered that a study of the methods of manufacture would be of assistance to Surveyors as to whether there would be any useful information gained in asking for a tube to be sectioned for examination and it has been the Authors' own personal experience that most tubemakers would co-operate.

With regard to the examination of internal surfaces of tubes, the Authors agree with Mr. Ozols' comments and whilst they sympathise with him, they still feel that in cases such as these, the recognition of laminations can only be acquired by experience. It may be of some satisfaction to Mr. Ozols to know that in cases of doubt the use of a reflecting mirror, fitted on the end of a telescopic rod, used in conjunction with the lamp on the end of a stick, would enable a Surveyor to see laminations when present and in doing so, would place him in a position to recognise these when carrying out routine examination of the interior of the tube with the aid of a lamp at the end of the tube.

The telescopic rod is that which was used as the wireless aeriel fitted to the R.A.F. rubber dinghy and obtainable in this country as surplus war stock.

The Authors assume that scars in hot rolled tubes are scores running longitudinally along the bore of the pipe. If this is the case, then the only workable tolerance that can be given is that if the score is round on the bottom, i.e., if it is a radial groove then it is not a weak point; if, on the other hand, it is sharp on the bottom, then the defect is inherent in the tube structure and the tube therefore should definitely be rejected. It may be, of course, that these scores are caused by scale inclusion which has been rolled in, but it is considered that refusal to accept such tubes until better rolling conditions maintain at the particular mill, should practically eliminate such trouble.

In conclusion, the Authors would like to thank Mr. Ozols for the great interest he has displayed in this paper and to express the hope that his questions have been satisfactorily answered.

PRINTED BY LLOYD'S REGISTER OF SHIPPING
AT GARRETT HOUSE
MANOR ROYAL, CRAWLEY, SUSSEX, ENGLAND

JULY, 1954

PRIVATE AND CONFIDENTIAL

LLOYD'S REGISTER STAFF ASSOCIATION

SESSION 1952-53
PAPER No. 3

ALIGNMENT IN MARINE ENGINES

Part I:

TURBINES TO PINIONS

By

B. HILDREW

LLOYD'S REGISTER OF SHIPPING,
71, Fenchurch Street,
LONDON, E.C.3.

The Author of this paper retains the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals

ALIGNMENT IN MARINE ENGINES

Part I: TURBINES TO PINIONS

By B. HILDREW

THE Engineering Research Department has dealt with a number of problems which involve the alignment of engines and shafting in ships. It is thought that the subject may be of general interest, and it is proposed to produce a series of monographs on the various aspects of such work.

1. The Alignment of Turbines to Pinions

The turbine is connected to the pinion by means of a flexible coupling. The purpose of the coupling is to permit of axial float of the turbine rotor and of the pinion; it is, however, capable of accommodating a small amount of malalignment between these two parts. Any malalignment will result in a proportionate amount of wear, therefore it is imperative that true alignment should be provided, due allowance being made for the operating conditions, i.e., bearing clearances and reactions. Any sign of frettage in the coupling is an indication of lack of lubrication or lack of truth. Experience has shown that the latter is the most probable cause.

If the wear pattern on the tooth form suggests that the pinion itself is not lying true to the remainder of the gearing, this matter must be investigated first and corrected in the usual way before pinion/turbine alignment is considered. The techniques herein described assume that the pinion is lying true to the remainder of the gearing and that the truth of the turbine to the pinion shaft is in question.

TYPES OF FLEXIBLE COUPLING

There are two types of flexible coupling in common use:

1. The Fine Tooth Coupling.

This coupling (Fig. 1) is formed by two hubs each possessing 30 to 40 radial teeth. One hub is attached to the turbine and the other to the pinion shaft. Mating with each of these hubs and interconnected by a concentric sleeve are two annular members having internally the appropriate number of teeth.

2. The Parsons Type Coupling.

This coupling (Fig. 2) is constructed in a similar way to the fine tooth coupling but the two hubs have 8 to 16 radial claws instead of teeth.

In another design (Fig. 3) referred to as unshrouded, the mating claws are machined into the thickened up end portions of the sleeve, the external diameter of which is the same as that over the hub claws.

Malalignment in either the Fine Tooth or the Parsons type coupling is a combination of two effects:—

(*a*) Lack of concentricity of the turbine axis to the pinion axis. This is termed parallelism; and

(*b*) Inclination of the axis of the turbine to the axis of the pinion.

The usual shop practice adopted to align the turbine and pinion housings is to place a mandrel in each housing with muffs attached to the contiguous ends. With the aid of a clock gauge secured to one mandrel and located radially on the other and with feeler gauges to measure the gap between the muffs, readings are taken at the top and bottom and at either side while one mandrel is rotated at 90° intervals through one revolution. This method lends itself to considerable accuracy provided the following precautions are observed:—

(1) Both muffs to be rotated the same amount before each reading is taken.

(2) The same relative measuring points to be used on both muffs.

By this means it is possible to cancel out any errors of each muff relative to the mandrel. The method is, however, a clumsy one in that the turbine rotor must be lifted, which is not always convenient. The methods described below will give the same accuracy of measurement and have the advantage that turbine and pinions are undisturbed.

GAUGING TECHNIQUE. Method A.

This method is recommended as being the easier and simpler of the two, and possibly the more accurate. It can be applied to any of the types of coupling described above, the only variable being the length of the central rod, which is determined by the span between the hubs. Fig. 4 (a) shows a schematic arrangement of the equipment.

The coupling sleeve and annular members are removed, leaving the hub portions secured to the pinion and turbine shafts. Two flat mild steel discs are secured to each of the faces of the coupling hubs. The disc attached to the pinion hub has a central rod fitted to it approximately coaxial with the pinion. The disc attached to the turbine hub is fitted with an arm radially displaced and approximately parallel to the turbine axis. Two dial gauges measuring to ·001 in. are radially attached to this outer arm such that their centrelines are a convenient and known length apart. The gauges register on the central rod. The two discs are marked off at 90° intervals and numbered as shown in Fig. 4 (b).

That the rod should be truly coaxial and that the arm should be truly parallel are not important, but it is absolutely essential that the rig is rigid and does not deflect under its own weight.

By rotating the turbine and rotor through identical angular displacements as shown by pointers on the casing, readings are taken with the corresponding marks 1, 2, 3, & 4 on top. Care must be taken to free the pinion from the main wheel and allow it to lie in its bearings. From the readings the appropriate malalignment and parallelism of the turbine are deduced. In this method the correction for parallelism is made sufficient to permit the centre lines of the pinion and turbine to intersect at the midpoint between the two dial gauges, and the inclination of the turbine axis is calculated from that point.

An H.P. turbine/pinion arrangement connected by a fine tooth coupling provides the following example which will explain the method :—

DIAL GAUGE READINGS

Number on top	1	2	3	4
Forward gauge 1/1000 in.	0	14	36	20
After gauge 1/1000 in....	0	12	29	18

A positive increase in the dial gauge reading, obtained when rotating the arm through 180° commencing with position 1 on top, indicates that the particular gauge is high relative to the pinion. A negative increase indicates that it is low. Consider the vertical plane

Forward gauge 36 - 0 = ·036 in.

After gauge 29 - 0 = ·029 in.

These differences represent an error equal to twice the eccentricity of each gauge about the central rod. To correct for parallelism only, so that the centrelines of the pinion and the turbine may intersect at the midpoint between the dial gauges, the turbine centreline would have to be lowered an amount corresponding to half the mean of these two readings (·01625 in. in Fig. 5(a)).

The angular malalignment is then all that remains, as is shown in Fig. 5(b). To correct for this the turbine feet would have to be lowered a further amount.

Distance from midpoint between dial gauges to midpoint of the after turbine foot = 17 in.
and of forward turbine foot ... = 88 in.

Centre point of forward foot would have to be moved

$$\frac{1{\cdot}75 \times 17}{3} = {\cdot}010 \text{ in.}$$

and centre point of after foot would have to be moved

$$\frac{1{\cdot}75 \times 88}{3} = {\cdot}051 \text{ in.}$$

To correct for parallelism and angular misalignment the midpoint of the forward turbine foot must be lowered

·016 in. + ·010 in. = ·026 in.

and the midpoint of the after turbine foot must be lowered

·016 in. + ·051 in. = ·067 in.

Consider the horizontal plane : the readings are

Forward gauge 20 - 14 = ·006 in.

After gauge 18 - 12 = ·006 in.

It will be seen that, to correct for parallelism in the horizontal plane, the turbine must be moved ·003 in. bodily to port. There is no malalignment and, as the parallelism error is only ·003 in., it is not worth while moving the turbine that amount.

GAUGING TECHNIQUE. Method B.

This technique is applicable to the Parsons type coupling only, which should be in the "as running" condition, i.e. with sleeve joints rigidly bolted together.

If the equipment described in Method A is not readily available, feeler gauges may be used to measure the clearances between the sleeve and the radial claws. It is difficult to take the necessary readings on the shrouded type, and great care should be exercised when so doing.

When using the feeler gauge the readings must be taken at the same place every time—the midpoint of the end of an internal radial tooth is most suitable.

In the unshrouded type, readings may be taken at either A or B (Fig. 3). In the shrouded type it is only possible to take readings at B. Care must be taken that either position A or position B is used consistently and that the correct interpretation is made of the readings taken. Clearly a large reading at A means the sleeve must be raised, whilst at B it would mean that the sleeve required to be lowered. Before taking any readings the sleeve must always be free axially in the radial claws.

Appropriate claws at about 90° intervals are chalk marked 1, 2, 3 & 4 as in Fig. 3. With No. 1 on top, feeler gauge readings are taken at positions 1 and 3 at the turbine and at the gearing end.

The assembly is then turned until No. 2 is on top, the coupling is freed axially, and the readings at positions 1 & 3, now horizontal, are again taken at both ends. The operation is repeated at 90° intervals for two revolutions in order that a check on the readings may be obtained. Where the axial float of the sleeve is considerable, the sleeve can be pushed aft against a stop of such a thickness that only one set of feelers suffice to take all the readings.

Care should be taken not to force the feelers in as this may disturb the position of the sleeve and thus cause errors of measurement. The actual fore and aft position of the sleeve is not important as long as it is not displaced during any set of readings at any one position; this is because only the differences between readings obtained at 1 and 3 are used to determine the malalignment.

The following example is of an unshrouded type of coupling and all the readings were taken at point B :—

GEAR END.

Number on top	1	2	3	4
Feeler gauge reading at Position 1 (1/1000 in.) ...	66	46	46	48
Feeler gauge reading at Position 3 (1/1000 in.) ...	76	52	48	58

TURBINE END.

Number on top	1	2	3	4
Feeler gauge reading at Position 1 (1/1000 in.) ...	38	50	41	50
Feeler gauge reading at Position 3 (1/1000 in.) ...	40	58	51	56

Consider the vertical plane, i.e. readings taken with 1 on top and 3 on top. Take the difference (1 - 3) and with due regard to sign draw a sketch of the alignment Fig. 6(a).

To align sleeve to pinion :

Sleeve is throwing 10-2 = ·008 in. at pinion claw
Diameter of claw = 10·6 in.
Length of sleeve = 33·6 in.

$$\therefore \text{ The sleeve must be raised } \frac{\cdot 008 \times 33 \cdot 6}{10 \cdot 6}$$

= ·025 in. at the turbine end.

As the differences of the (1 - 3) differences at the pinion and at the turbine are the same, i.e. ·008 in., it is obvious that this is a case of parallelism only, and to correct it the turbine casing must also be lowered ·025 in.

Consider now the horizontal plane, i.e. readings taken with No. 2 and No. 4 on top. Take the difference (1 - 3) and with due regard to sign draw a sketch of the alignment Fig. 6(b).

To align sleeve to pinion :

Sleeve is throwing 10 - 6 to Port = ·004 in. at pinion claw

$$\therefore \text{ Sleeve must be moved } \frac{\cdot 004 \times 33 \cdot 6}{10 \cdot 6}$$

= ·0126 in. to Starboard at the turbine end.

To bring turbine into line, the turbine would have to be moved bodily ·0126 in. to Starboard. The alignment will then be as shown in Fig. 6(c). It will be observed that the parallelism has been corrected but misalignment of the turbine is still present to the extent of ·002 in. over the coupling diameter of 10·6 in.

If the mid length of the aftermost and forward turbine feet are 10 in. and 70 in. respectively from the turbine coupling claw, it is necessary to move the midpoint of the after foot a further $\frac{\cdot 002 \times 10}{10 \cdot 6} = \cdot 002$ in. to Starboard and the midpoint of the forward foot a further $\frac{\cdot 002 \times 70}{10 \cdot 6} = \cdot 013$ in. to Starboard.

Thus to summarise :

The turbine must be raised completely ·025 in. and moved to Starboard ·0126 + ·002 = ·015 in. at midpoint of forward foot and ·0126 + ·013 = ·026 in. at midpoint of after foot.

On completion of this manœuvre the alignment should be rechecked and should be reasonably true.

Effect of Oil Film and Tooth Loading.

The amount the turbines must be moved in the vertical and horizontal plane is not truly indicated in the two examples given. The lack of alignment has been determined with the turbine and pinion lying in the bottom of their bearings. An allowance can be made for :—

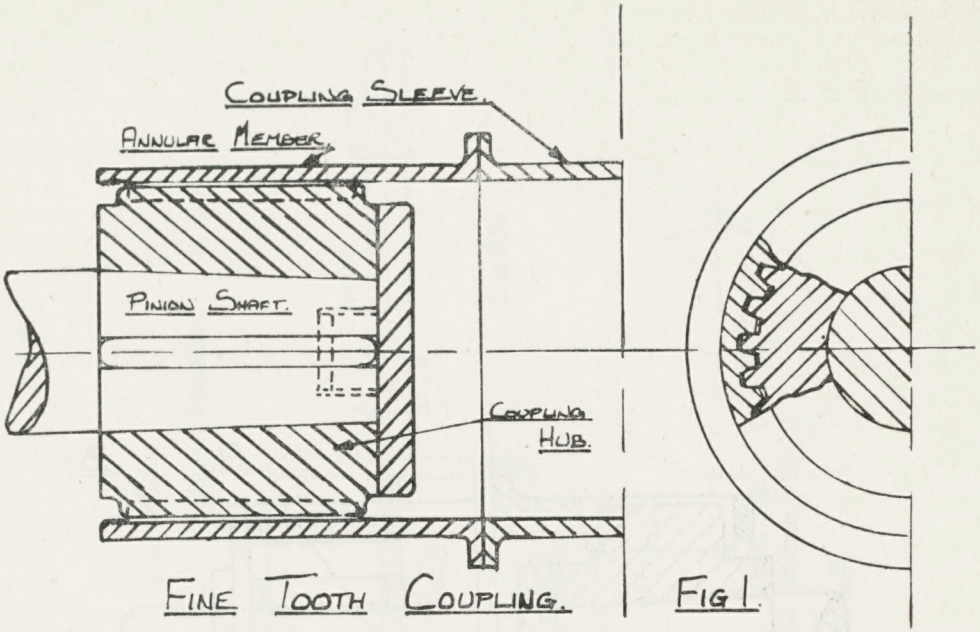
(1) The position of the pinion in its bearing when running ahead and subject to the loading of the primary wheel.

(2) The oil film under the turbine journal and the pinion journal when running. This may be assumed to be about 30% of the bearing clearance. The bearing clearance should be of the order of 1½ thousandths of an inch per inch diameter of journal.

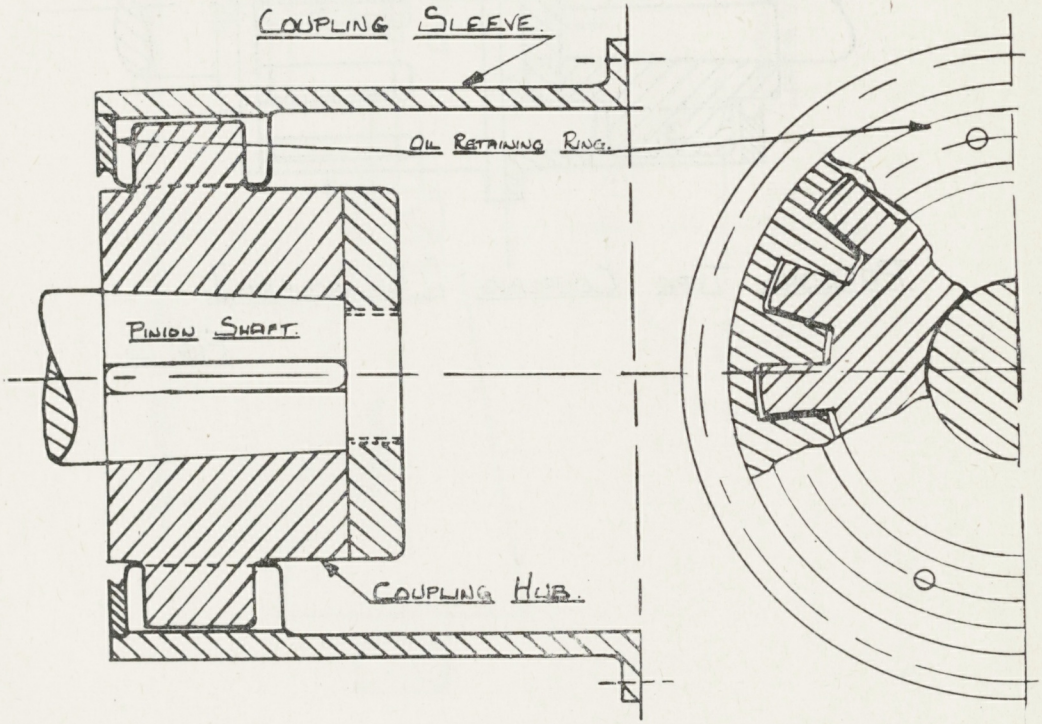
Under full load conditions it can be generally assumed that the pinion will run displaced from the wheel with which it is meshed in the direction of the resultant journal reaction. The direction of the displacement can usually be assumed to be at 90° to the split in the bearing shells. The running position of the pinion journals is therefore along this line, but displaced from the surface of the bearing shell an amount equal to the oil film. The vertical and horizontal components of this displacement must be added or subtracted as the case may be from the correction for alignment obtained during the gauging.

The allowance to be made for the running position of the turbine journal in its bearing is due to the oil film which is assumed to raise the rotor vertically by 30% of the bearing clearance.

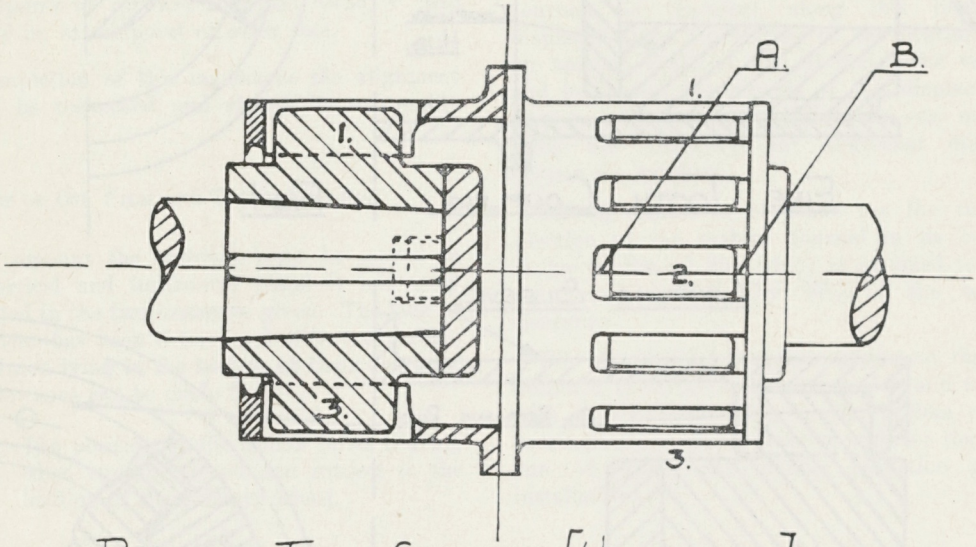
For all practical purposes, alignment readings obtained from the stationary pinion and turbine with the journals lying in the bottom of the bearings are probably near enough for the usual run of single and double reduction geared installations.



FINE TOOTH COUPLING. FIG 1.



PARSONS TYPE COUPLING. [SHROUDED]. FIG 2.



PARSONS TYPE COUPLING [UNSHROUDED].

FIG 3.

Schematic Arrangement of Alignment Indicator.

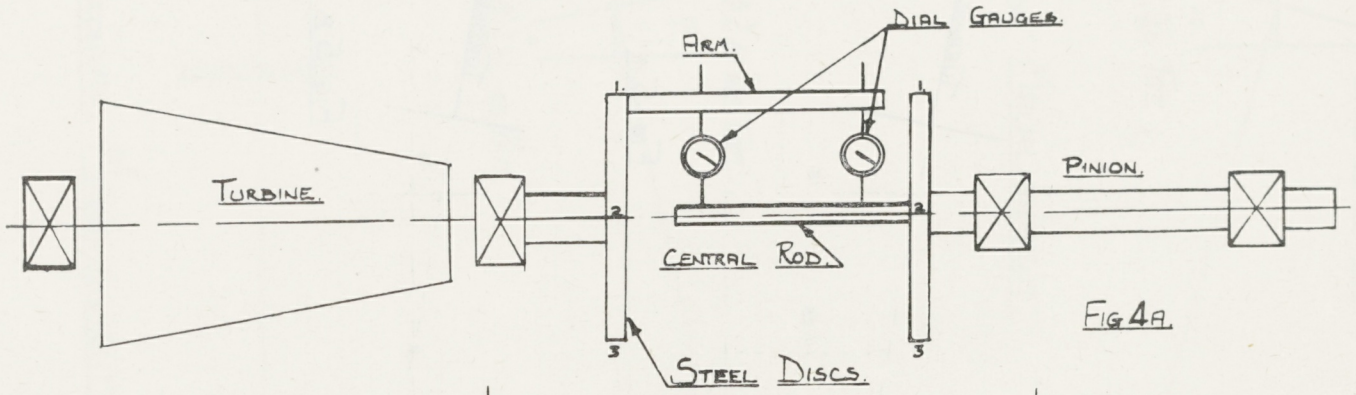
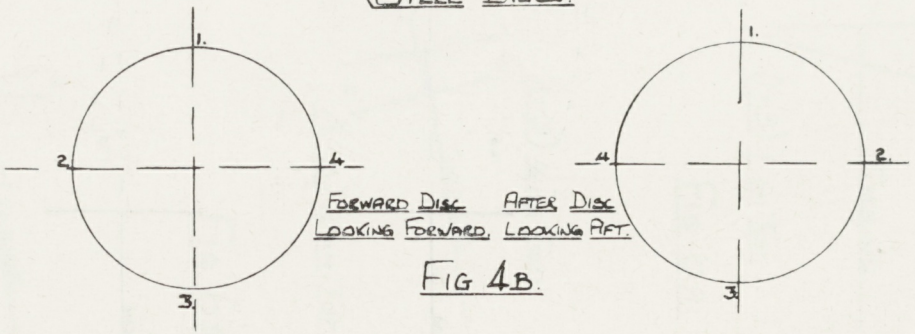


Fig 4A.



Forward Disc Looking Forward.

After Disc Looking Aft.

Fig 4B.

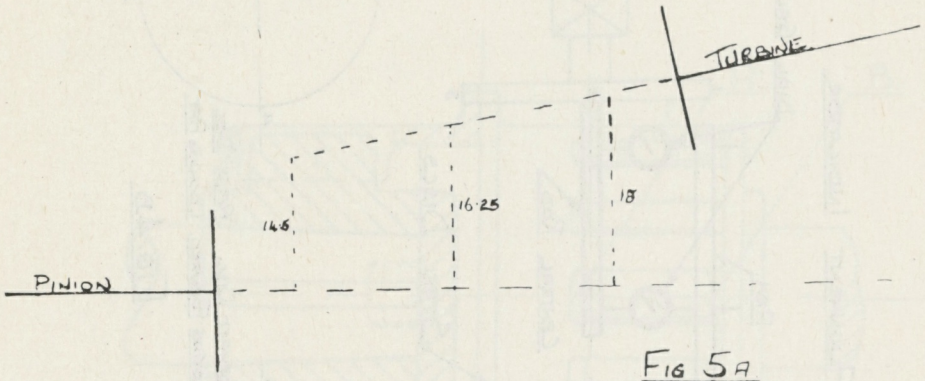


FIG 5A

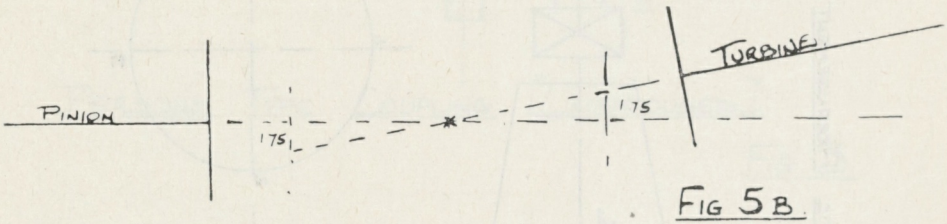
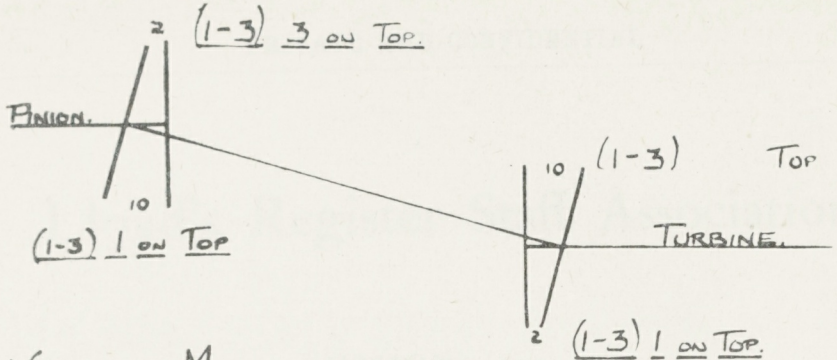


FIG 5B



Vertical Malalignment.

Fig 6A.

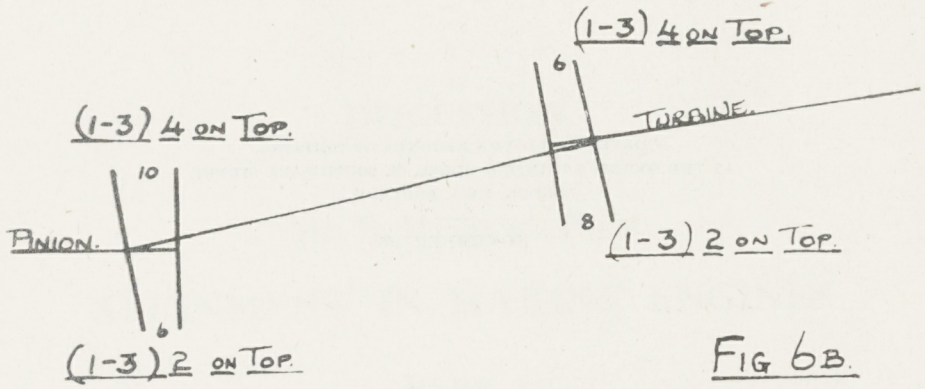
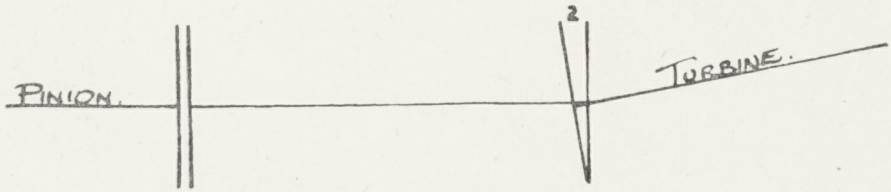


Fig 6B.



Horizontal Malalignment.

Fig 6C.

PRINTED BY LLOYD'S REGISTER OF SHIPPING,
AT THE SOCIETY'S PRINTING HOUSE, 64, SOUTHWARK STREET,
LONDON, S.E. 1, ENGLAND.

NOVEMBER, 1952

PRIVATE AND CONFIDENTIAL

Lloyd's Register Staff Association

SESSION 1952-53

PAPER No. 3

DISCUSSION

on

Mr. B. Hildrew's Paper

ALIGNMENT IN MARINE ENGINES

PART I

"Turbines to Pinions"

LLOYD'S REGISTER OF SHIPPING,
71, FENCHURCH STREET,
LONDON, E.C.3

The Author of this paper retains the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals.

ERRATA

ALIGNMENT IN MARINE ENGINES. PART 1.

"Turbines to Pinions"

by B. HILDREW.

Page 2, column 2, line 25.—"Centre point of forward foot would have to" *should read :*
"Centre point of aft foot would have to"

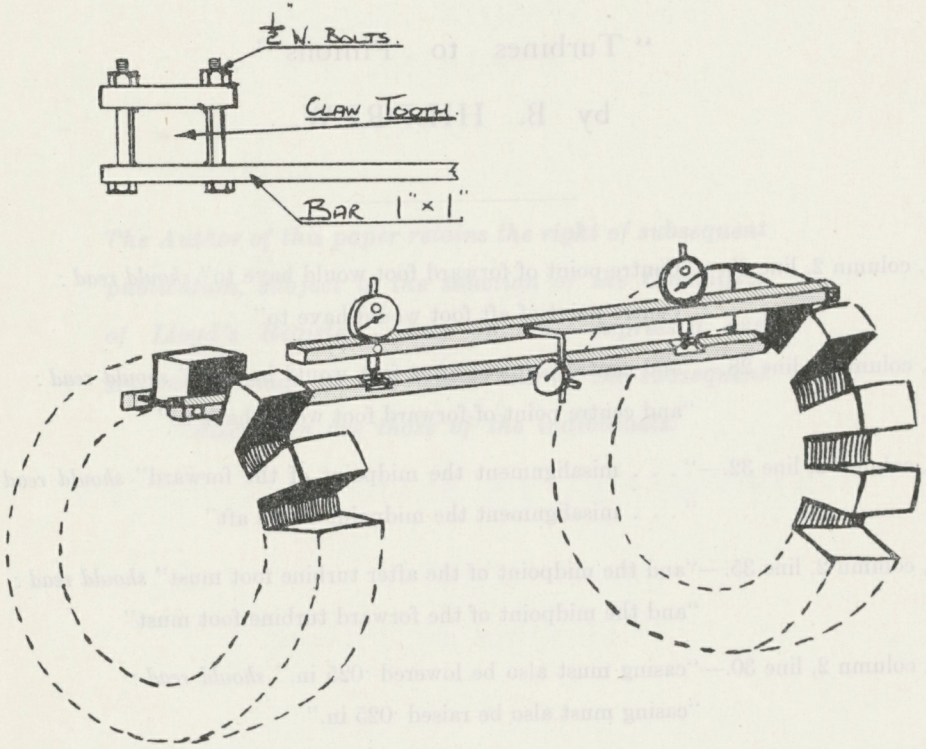
Page 2, column 2, line 28.—"and centre point of after foot would have to" *should read :*
"and centre point of forward foot would have to"

Page 2, column 2, line 32.—". . . misalignment the midpoint of the forward" *should read :*
". . . misalignment the midpoint of the aft"

Page 2, column 2, line 35.—"and the midpoint of the after turbine foot must" *should read :*
"and the midpoint of the forward turbine foot must"

Page 3, column 2, line 30.—"casing must also be lowered ·025 in." *should read :*
"casing must also be raised ·025 in."

Page 4, column 1, lines 11 & 12.—"at midpoint of forward foot and ·0126+·013=·026 in. at midpoint of after foot" *should read :*
"at midpoint of after foot and ·0126+·013=·026 in. at midpoint of forward foot."


½" W. Bolts.
Claw Tooth.
Bar 1"×1"

Discussion on Mr. Hildrew's Paper

ALIGNMENT IN MARINE ENGINES. PART 1.

"Turbines to Pinions"

T. W. BUNYAN.

In opening the discussion on Mr. Hildrew's paper, I said that the problem of turbine to pinion alignment was brought into prominence, a few years ago, by two failures of the claw couplings on wartime built vessels in which, to minimise the effect of underwater explosion on the turbine, resilient chocks had been fitted under the turbine feet. Due to lack of proper maintenance, the chocks had partially collapsed and had fretted, producing severe malalignment between the turbine and gearing. On opening up, the couplings were found to have fretted very severely in consequence, and fatigue failure of one of the heavy claws burst the coupling casing, fortunately without causing any other serious damage. In one case it was considered that the fatigue failure of the L.P. pinion which had also occurred could be attributed to the same cause.

Since that date the Department has been involved in the investigation of a number of cases of frettage of claw couplings, and has only recently dealt with frettage which had developed very rapidly in two large new vessels. The apparatus described by Mr. Hildrew in his paper was, in fact, used on both these vessels, which indicated considerable malalignment existing to a greater or lesser degree on both H.P. and L.P. turbines driving twin screws.

It is an interesting reflection that, as in the case of the two vessels referred to above, the claw couplings are seldom dismantled and opened out for examination unless the presence of severe vibration or noise indicates that something is amiss. Frettage of this type often develops at an early stage and it would seem to be good practice to open up and examine the couplings at the end of the guarantee period. One point should be mentioned and that is, before the alignment readings are taken the bottom half bearing shells of the pinions should be rotated such that the split in the bearing is horizontal, which will ensure that the pinion is not resting in the washed away portion of the horns of the bearing. This is important, otherwise appreciable malalignment will be indicated.

E. L. KNOWLES.

I should like to thank Mr. Hildrew for an interesting and informative paper, which he read to a very small but appreciative audience.

The simplicity and usefulness of his apparatus for checking and correcting alignment between turbines and pinions was ably demonstrated, but I cannot help wondering how many of the cases which he and his colleagues have been called in to investigate really go back to the time of installation of the machinery.

The method employed in the erecting shop at one very well-known firm that I know of, was to set up a heavy straight edge long enough to cover the rotor and pinion shaft journals at one setting. Micrometer readings were taken vertically and horizontally and the joint between turbine and gear case was then machined and/or filed to suit.

When erecting on board, this procedure was adopted again, rather than to rely on closing the joint between turbine and gear case.

The point about this is that it would be quite possible to close the above-mentioned joint without having true alignment of the two shafts.

Mr. Hildrew says, on page 1, that the usual shop practice is to place a mandrel in each housing and check the alignment with clock gauges and feelers. At the firm I was with, we tried mandrels but gave up the idea because of warping when they were lying idle for a period of time. In any case, I think this is a costly method unless a number of identical engines are under construction.

So far as my own observations go, I think the seatings of the average geared turbine set are of a substantial nature and rigid. I am, however, of the opinion that the same meticulous care taken in the alignment in the erecting shop should be repeated when installing in the ship, and that reliance on witness marks, feeler measurements in joints, etc., are a snare to be avoided.

L. R. HORNE.

Mr. Hildrew is to be thanked for giving very practical guidance to his colleagues.

There is a point on which I should welcome his opinion, that is, the degree of malalignment that arises from temperature changes in service. The alignment of new machinery is always carried out when the seatings, turbine and gear casings are cold. Under working conditions very considerable differences of temperature occur in these which, it seems to me, must produce malalignment. I understand that the Admiralty have made serious attempts to assess this but, so far as I know, it is not measured in Merchant Vessels.

With reference to gauging technique, method "A", it seems to me that no allowance is made for a possible deflection in the turbine rotor. Would it not be desirable to verify the truth of the turbine before proceeding as described in the paper ?

G. PICKERING.

The method "A" calls for no criticism or further explanation. It is simple, accurate, very convenient and quick for checking alignment on board ship. I do not like method "B" which could be troublesome.

In a case of probable malalignment I think it desirable to lift the rotor and try it in a lathe before deciding to move a turbine casing. It sometimes happens that a coupling is slightly eccentric due to skimming the rotor journal or journals to correct for slight bend which has occurred in service.

On page 1, under the heading "1. The Alignment of Turbines to Pinions", the Author says, "Any sign of frettage in the coupling is an indication of lack of lubrication or lack of truth. Experience has shown that the latter is the most probable".

In my experience "the latter" has not shown to be the most probable cause of coupling frettage, and I would put the causes in the following order:—

1. Faulty lubrication due to:

   (*a*) the supply of oil being carelessly directed.

   (*b*) blockage of oil ducts and clogging of claws or teeth by wax separated from the oil by centrifugal action.

2. Increased loading and precession of rotors and pinions due to pitching of vessel when kept up to full power in heavy weather or swell. Also axial shuttling of pinions.

3. Malalignment:

With any combination of these causes it is impossible to say which has pride of place after lubrication.

The subject of alignment is of much interest and this paper is a most useful contribution. I look forward to further instalments.

W. C. COWIN.

There has been a large number of renewals of the small tooth flexible couplings fitted in the geared turbines of "Victory" and C 2 type vessels built in the United States.

The lubrication arrangement has been modified in the fitting of a dam ring at the ends of the teeth and allowing a restricted amount of oil to discharge through holes at the largest internal diameter to carry out any solids that tend to remain centrifuged inside the coupling.

The change in alignment from idle to running conditions is a contributory cause to wear in the coupling teeth. Some builders line the couplings true on the faces with the pinion coupling ·001 inch to ·004 inch high and to port or starboard depending on the direction of the tooth pressure; others allow ·004 inch to ·006 inch on the perimeter, true on the faces, then when bolted to the gear case set the forward end of the outboard as much as ·060 inch to compensate for the expansion of the gearcase.

It is difficult for the owner to discover the cause of the failure, further, the incentive is not great, as production line methods have made the cost of new couplings surprisingly low.

S. ARCHER.

Mr. Hildrew's paper has the merits of conciseness and clarity and will undoubtedly repay careful study by those colleagues who may not be familiar with the type of gauging techniques described. As a first "helping" it augurs well for the further instalments of the series on alignment which we are to expect later.

In commenting on the details of the paper it is noted the Author states on page 1 that "any sign of frettage in the coupling is an indication of lack of lubrication or lack of truth". Unfortunately it has been found that lubrication alone will not necessarily inhibit frettage, since it is almost impossible to eliminate dissolved oxygen in the oil which is one of the essential factors in the corrosion process. Dr. Tomlinson* also found that even if relative motion is reduced to apparently quite negligible amounts (of the order of molecular dimensions) corrosion still occurred and that this was almost independent of normal pressure. He also found that corrosion was worse with a high surface finish. Again, lack of truth is not always the culprit, shuttle action from pinions being probably at least as frequent a cause. With severe axial vibration of line shafting in multi-screw single reduction installations severe frettage wear of claw couplings has also been experienced.

At the present time full scale tests are projected at Pametrada on both fine tooth and claw type couplings to determine the quantitive effects of misalignment and of various combinations of materials on the rate of frettage corrosion and wear. A particularly promising combination appears to be bronze on steel, which has seen good service in power station work in the form of renewable bronze inserts. Barrelling of the coupling teeth is another development from successful power station practice which is receiving increasing attention in marine applications.

Of the gauging methods described in the paper, method "A" is undoubtedly the most accurate and convenient. From personal experience one of the drawbacks of method "B" is that it is usually difficult, if not impossible, to take the readings at position (3) owing to lack of clearance between the coupling and its casing.

*"Engineering," 10th March, 1939, p. 293.

In method "A" it is concluded that the distance between the dial gauges in the example quoted was as little as six inches. If so, it would seem desirable to use the maximum possible span between gauges, having regard to the large magnification (up to something like 30 times) in translating the readings into corrections at the turbine feet.

In the concluding section on the effect of oil film and tooth loading (last sentence) the Author is not very clear as to whether, in his opinion, the corrections for pinion and rotor displacements in running position are worth while or not. Could he confirm this, or otherwise?

Although some attempt to allow for these corrections appears desirable, particularly having regard to the fact that one pinion may be loaded downwards whereas its partner may have its load taken on the bearing keeps, it should not be overlooked that, so far, very little has been said, or indeed is known, of what may well constitute a considerable source of errors in turbine-pinion alignment, namely differential thermal expansion between turbine casing and gearcase. For example, if the turbine centre line is 20 inches above the level of its feet and a mean temperature rise of no more than 200° F. is assumed relative to its temperature when alignment is gauged cold, the average lift of the turbine rotor will be:

$$20 \times 200 \times \cdot 0000066 = 0 \cdot 026 \text{ inch.}$$

This is a point in favour of endeavouring to arrange the level of turbine feet as high as possible relative to the rotor centre line, particularly in H.P. turbines.

Again, consider a two-turbine job, with pinions arranged at or near the sides, i.e., with a considerable athwartships span between their centre lines. Assume a temperature rise of the main gearcase of, say 40° F., above the ambient temperature of the ship's structure between the forward turbine feet and that the fixed feet are carried on the main gearcase. If the span between pinion centre lines is, say 100 inches, then the outboard displacement of the after turbine feet relative to the forward feet due to thermal expansion of the gearcase will be:

$$\frac{100 \times 40 \times \cdot 0000066}{2} = 0 \cdot 013 \text{ inches.}$$

Some vertical rise would also be expected, of course. These figures are purely illustrative, but do serve to indicate the need for some research on this aspect of turbine-pinion

alignment. It is known that in America the G.E.C. have conducted considerable researches on their own designs and that in consequence they arrange for appreciable deliberate misalignment of turbines when cold.

AUTHOR'S REPLY

It is regretted that, due to haste in production, the errors listed in the errata were not eliminated prior to publication. In writing the paper the Author found great difficulty in expressing simply the method adopted. In practice, however, it is easy to visualise what correction is needed to align the turbine from the readings obtained and a repetition of the method after adjustment is an additional safeguard.

The technique is severely practical and simple and it is surprising that it has not evoked more interest in the outports. This was especially apparent in that no one appears to have noticed the errata listed above.

In order that the process may be reduced to one of automatic infallibility the following formulæ have been devised.

These formulæ only apply if:

1. The arm supporting the gauges is attached to the turbine;

2. The turbine and pinion are turned clockwise looking forward;

3. The reading of the dial gauge is interpreted as:

(*a*) positive when the plunger is pushed in from position at No. 1;

(*b*) negative when the plunger comes out from position at No. 1.

Let D_1 be dial gauge nearest turbine.

Let D_2 be dial gauge nearest pinion.

Readings obtained are entered in the table below:—

Number on Top	...	1	2	3	4
Reading from D_1	...	a	b	c	d
Reading from D_2	...	e	f	g	h

Let L_1 = distance of centreline of after turbine foot to midpoint between dial gauges.

L_2 = distance of centreline of forward turbine foot to midpoint between dial gauges.

X = Distance between dial gauge plungers to 0·1 inch.

Then:—

Vertical correction (in thousandths of an inch or mm. depending upon dial gauge used).

$$\text{At forward foot} = \frac{(a\text{-}c)+(e\text{-}g)}{4} + L_2\left[\frac{(a\text{-}c)-(e\text{-}g)}{2X}\right]$$

$$\text{,, after foot} = \frac{(a\text{-}c)+(e\text{-}g)}{4} + L_1\left[\frac{(a\text{-}c)-(e\text{-}g)}{2X}\right]$$

Horizontal corrections.

$$\text{At forward foot} = \frac{(b\text{-}d)+(f\text{-}h)}{4} + L_2\left[\frac{(b\text{-}d)-(f\text{-}h)}{2X}\right]$$

$$\text{,, after foot} = \frac{(b\text{-}d)+(f\text{-}h)}{4} + L_1\left[\frac{(b\text{-}d)-(f\text{-}h)}{2X}\right]$$

If signs have been correctly observed then for vertical corrections:

Negative result means to lower.

Positive result means to raise.

For horizontal corrections:

Negative result means to move to Port.

Positive result means to move to Starboard.

The example given on page 2 of the paper was, in fact, taken from the two twin-screw vessels quoted in Mr. Bunyan's contribution. The Port H.P. turbine was corrected while the Starboard H.P. turbine was left as fitted. We must have got the correction right in practice as the noise level of the Port gearing dropped and the excessive wear and frettage in the Port H.P. claw coupling ceased.

Mr. Knowles states that it is essential that the alignment be checked carefully in new construction. This should preferably be done with the turbine and pinion in position and, in the case of twin-screw vessels, with both sets of engines in the ship.

Mr. Pickering's contribution which contains the experience of many years in the Society's service is appreciated. Naturally when presented with a problem of malalignment the Research Department tries to obtain the history of the turbine, coupling and pinion. In the case of trouble caused by a bent rotor the gauging technique described checks the alignment only, no matter how bent the rotor may be. This is one of the great assets of the method described. To Mr. Pickering, and Mr. Horne who has also raised this point, the short answer is that it would probably prove cheaper in the long run

to do an alignment check (maximum time 2 hours) before proceeding to break the turbine casing joint.

As far as the listed causes of frettage in claw couplings are concerned, lubrication is certainly the prime cause if the history of the subject is considered. However, more attention is now paid to lubrication in new construction and a considerable amount of old construction has been modified to eliminate the faults implicit in 1(*a*) and (*b*) of Mr. Pickering's contribution. The problem today does seem to be more one of malalignment. Increased loading and precession in heavy weather should not damage a properly lubricated and aligned coupling of approved design.

Axial shuttling of pinions, stems from a number of causes and the frequency of shuttling is a guide to the cause. The Engineering Research Department is equipped to determine such a frequency, but it is generally beyond the limited tools in the hands of a practical Surveyor in an outport. The possibility of such shuttling must of course be borne in mind when investigating damage in claw couplings and gear teeth, but here again, the causes of axial shuttling are appreciated and it is becoming a very rare occurence.

Mr. Archer's contribution touches on all the possible combinations of trouble. The use of different materials in combination in the coupling may prove to be a considerable step forward, but the problem of malalignment will remain, especially so when the high temperatures of modern steam plants and of gas turbines become common marine practice.

Barrelling of coupling teeth is of great value and every coupling should be so treated.

I agree heartily with the condemnation of method "B". It requires very clear thinking and should only be used when the design of the gearing does not permit of a ready removal of the coupling sleeve.

In reply to the criticism about the short distance of 6 inches between the two clock gauges, there is a practical reason for this in that the light alloy arm carrying the gauges may become too long and deflect under its own weight, plus the weight of the gauges.

Where the turbine and pinion claws have been a considerable distance apart it has been found necessary to have a central tube of appropriate length and rigidity fitted in lieu of the central rod, but the distance between the gauges has been maintained at 6 inches.

Further, if the gauge length is increased, it probably means that the new gauge readings are of the order of ·0005 inch more accurate, this is of no importance. If the gauge length had been doubled in the example on page 2 of the paper, the calculations to determine how much the mid point of the forward turbine foot must be lowered would have given a figure between ·064 inch and ·070 inch. This is only a maximum of ·003 inch from the determined value on a six inch gauge length.

Whether the corrections for pinion and rotor displacement due to tooth load and oil film in the running position are necessary, depend on the bearing clearances. If the bearing clearances conform to 1–1½ thousandths of an inch per inch diameter of journal, then the correction is of no consequence. If, on the other hand, a six inch diameter journal has ·025 inch clearance, as the Author recently found, then such a correction is necessary unless the bearings are remetalled. To make the practice uniform, the Research Department corrects for one half of the feeler gauge reading between the journal and the top half bearing, when the pinion is out of mesh. This is found sufficient for practical purposes.

Mr. Horne, Mr. Archer and Mr. Cowin, raise the question of differential thermal expansion. This can be limited by good design, although the Society's Research Department have measured a turbine thermal lift of ·035 inch in a post war vessel. It would be sensible to make allowance for a movement of such proportions, but the decision to do so must depend on the amount and sense of the total malalignment found in any particular case, and on the design of the turbine casing. With each case to be decided on its merits, it would be advisable for the Surveyor to ignore temperature effect. If he appreciates that the design is the main culprit, a figure of ·025 inch is probably the safest to work to. It is not thought that the athwartship malalignment necessary to correct for temperature is as great as suggested by Mr. Cowin; in fact the Society has yet to find a case of any malalignment of that order and sense. It would seem to indicate an extremely hot installation as a calculation along the lines proposed by Mr. Archer, shows that the Chief Engineer could fry eggs on the gearcase.

It is probable that Mr. Archer's figures for transverse malalignment are nearer the truth or even on the large side. Until further evidence is available judgment is reserved.

Despite the low cost of couplings in Mr. Cowin's continent, dollars discourage the European owner and in any case on this side of the Atlantic marine machinery is expected to last the life of a ship.

In the case of the Parsons claw coupling a lash up as shown in the figure has been found satisfactory when a quick check on alignment has been desired. The centre gauge is brought to zero at each of the four positions thus automatically assuring the reading is taken with the bars in the same relative position. The bars should be of a light metal to prevent deflection under their own weight.

In conclusion, the main assets of the technique are re-emphasised.

1. The minimum of dismantling is required.

2. No matter how distorted the rotor and pinion may be, the technique determines that the bearings of turbine and pinion are true.

3. The alignment check can be done comfortably in two hours by Surveyors.

4. Despite all the possible combinations of trouble in the form of lubrication, thermal distortion, shuttling, etc., it eliminates the most common cause of frettage in claw couplings.

PRINTED BY LLOYD'S REGISTER OF SHIPPING
AT GARRETT HOUSE, MANOR ROYAL, CRAWLEY
SUSSEX, ENGLAND

MAY, 1954

PRIVATE AND CONFIDENTIAL

LLOYD'S REGISTER STAFF ASSOCIATION

SESSION 1952-53
PAPER No. 4

THE SURVEY OF VERY OLD SHIPS

A SYMPOSIUM

LLOYD'S REGISTER OF SHIPPING,
71, Fenchurch Street,
LONDON, E.C.3.

The contributions to this symposium have been edited by the Reading Committee of the Staff Association who wish to apologise to contributors for any omissions which have been found necessary in the interests of economy or to avoid redundancy.

THE SURVEY OF VERY OLD SHIPS

A SYMPOSIUM

MR. P. F. BALFOUR, DURBAN

IN spite of the present tendency to convert coal burning vessels to oil burning, many old vessels continue to burn coal in the boilers. The use of coal as a fuel can lead to severe and costly wastage to the vessel's structure.

At Periodical Special Surveys very careful attention must be given to side and cross bunkers, and to the spaces below boilers, including tank top plating and bilges forward of the boilers, within the stokehold, and surveyors should insist on these spaces being thoroughly cleaned and adequate lighting being available when carrying out a survey.

When cleaning fires in coal fired boilers, the red hot ash which is drawn from the furnaces is quenched with sea water. It is rare indeed, to find that the stokehold floor plates are such a good fit that a quantity of wet ash does not find its way through to the tank tops, where it is left to lie, thus offering perfect conditions for corrosion, the result being the rapid wastage of tank top plating, boiler stools, collision chocks, ballast piping, etc. Whilst on the subject of ash, the surveyor is reminded of the importance of the ash shoot.

The electrical circuits in the stokehold and those which pass through a bunker, should receive very careful attention, due to the deterioration of the insulation of the cables, which is accentuated by the combination of heat and dampness.

The majority of ships of this type carry bulk cargo such as coal and phosphates, which can give rise to rapid deterioration of the steel structure, and a careful survey of holds is called for. Heels of shell frames, where the grooving of the shell plating can take place, is an example of defects often found. Very old ships are not often to be found with deep tanks, and it is a common practice to flood a hold, particularly the after hold, when a vessel encounters adverse weather on a light ship passage. This, of course, will tend to promote corrosion when surfaces are not properly cared for. Thorough scaling and coating of steelwork in bunkers, stokeholds and holds at regular intervals, for example at Special Surveys, is most important, and will save an Owner considerably more than the cost involved, in the long run.

As a result of experience gained through years of practice, the older surveyor can judge the thickness of a plate by sounding with a hammer, or, which is frequently preferred, a short bar, such as a handrail stanchion. The younger surveyor is naturally not so adept at this practice, and should not hesitate to call for test holes when in doubt. The average superintendent will raise no objections, provided this method is not overdone.

In many old ships, cables are only ranged at Special Surveys and are usually found to be heavily scaled. In these ships the chain locker is also neglected.

The cement in the bottom, particularly in way of double-bottom tanks used for ballast only, viz. sea water, is important. In No. 1 or forward double-bottom tank, which often suffers from pounding, the cement can be loose, although not badly disturbed, and the surveyor must ascertain that cement is adhering. It has been found, after removal of loose cement, that fastenings of floors and bottom angles have been slack and useless, and also, that severe corrosive wastage of rivet heads and plates has taken place.

Repairs To Very Old Ships.

It is frequently the case, that the Owner of this type of ship, will require the Special Survey to be completed, and all the surveyor's recommendations made, in order that he may know the cost of putting the vessel through survey. It is very difficult to comply fully with this request, as the most conscientious survey will not reveal defects and deterioration which will only become evident after the removal of adjacent material, plates, etc. The experienced superintendent is aware of this, but it is often advisable to point this out to an Owner's representative when he is endeavouring to arrive at a final cost.

Doubling Of Plates.

The fitting of doubling plates is an accepted form of repair, but the practice is frequently abused, or overdone.

A doubling plate can give considerable trouble through water finding it's way between the original plate and the doubling plate. A good example is the doubling of a plate which is part in way of the forward hold and part in way of the fore peak tank; water finds its way between the plates, and endless trouble is caused in locating the exact source of leakage. It is a good policy to try to persuade superintendents to renew this type of plate, the difference in cost of renewal against doubling being small.

Boilers.

In the case of very old ships, the boilers, which are also very old, call for careful and thorough survey. Points to which particular attention should be given are :—

Corrosive wastage of furnaces on line of bars.

Mechanical grooving in way of end plate flanges.

Corrosive wastage of combustion chamber plating, particularly knuckles of combustion chamber back plates.

Boiler mountings and steam pipes require careful survey.

I would like to add that I have surveyed several old boilers which have been in perfect condition, and on complimenting the Chief Engineer, usually an elderly gentleman of the old school, he has remarked, "Yes, and none of your new fangled water treatment, just lime and soda, coupled with regular and thorough cleaning." I think it should be added, "and first class workmanship during construction."

MR. W. M. BALFOUR, BELFAST

Such a title raises the question of what constitutes a very old ship. If deterioration is the criterion a tanker at 12 years old can be a "very old ship." A passenger ship at 30 years old may be scrapped, because with modern improvement she is obsolescent, but she may be and probably is in good condition from a wear and tear point of view. The standard is still further confused because ships as they get up in years usually have a special survey where renewals are extensive, followed by one or two surveys at four year periods where renewals are moderate. A ship can be drilled at 24 years of age, and no shell renewals found necessary, but it is unlikely that a cargo ship can be maintained until 36 years old without extensive renewals being necessary at one of the intermediate surveys. All that can be said about surveys of very old ships is that Surveyors can take nothing for granted and should avoid being misled by a notation that the shell was drilled four years previously.

In local ships it is helpful to consult the drilling sheet of the survey held 4 years previously, and it would be a good practice to attach a copy of the last drilling sheet to the deferred reports. This would apply specially to ships with the British Corporation Class which must be drilled at all surveys when the ship is 20 years or over.

In old ships Surveyors should have no difficulty with local wear down, e.g., in a ballast tank under boilers or even in a dry tank that has not been kept dry or well ventilated. Only experience can tell the best method of carrying out repairs. In other words the obvious can be dealt with, but what is not so obvious can be overlooked. Heavy rust can have a smooth surface and be well coated. In one survey of an old ship, the margin outside brackets appeared to be in good condition with a good surface and well coated, but they appeared to be extra heavy. A 2 lb. hammer applied to the brackets made no impression, but when applied to the bottom edge of the manhole, the edge opened out into three thicknesses. When a maul was applied, quarter-inch scale fell from both sides. All the brackets were paper thickness. This particular hold had been used regularly for the carriage of salt in bulk and before loading each cargo all steel work had been cement coated.

In a passenger ship the open promenade wood deck was painted white on the under side, but the paint was badly blistered; they were water blisters, not sun blisters. When the wood deck was drilled it was found to be in a sodden, wet and very poor condition.

In recommending repairs care should be taken to avoid introducing discontinuities. In coasting trade ships with raised quarter deck, it is not uncommon to find that the deck plating has been doubled and all the doublers stop at the bridge front and bridge after bulkhead.

The easy way out should never be taken unless the finished job is satisfactory. Doubling an inside strake and welding is an easy way out. When a riveted doubler is fitted holes have to be drilled along the edge with tack holes within the area of the plate, and if the plate is too thin for reasonable riveting the shell plate should be renewed. With a welded doubler there is no such safeguard unless the Surveyor drills extra holes to ensure that the shell plate all over has a reasonable thickness.

In old ships, longitudinal strength may become an important question. The British Corporation Rule of drilling at every survey after 20 years old is onerous, but it is effective as a check on longitudinal strength.

Some ships may require extensive repairs at the first drilling survey and a few may survive with moderate repairs until 36 years old, but at the intermediate surveys between these drilling surveys longitudinal strength should always be considered, especially with ships with concentrated loading amidships.

If the wear down permissible with isolated plates is taken as a general guide and applied indiscriminately to the midship half length of the ship without consideration of longitudinal strength the result can be far from satisfactory.

MR. D. S. FORSYTH, GOTHENBURG

Severe wastage can be found generally, and especially in such places as between "wind and water," and where there is inadequate ventilation, damp, heat and abrasion. Also in any inaccessible positions where there is consequently lack of maintenance.

Such positions are the following :—

SHELL.

Keel. Flat keel plates in way of blocks. Coffin plates aft.

Garboard Strake. Under boiler if bar keel is fitted.

Bottom. At strum boxes, at toes of frames and intercostal lug connections, especially at the after end of tanks. Wasted and eroded rivet points and erosion of caulking edges, forward.

Bilge Strake. At cement chock edges, especially forward. Where chain cables chafe. At ends of bilge keel connections.

Side Plating. At after hold in way of hatchway. Under scuppers, discharges and ash shoots, especially rivet points. Behind accommodation linings. At frame heels forward especially near side scuttles. At ends of stringer shell lug connections.

General. At joggles of plating. At counter plating of elliptical sterns. Under or behind portable tanks. At trawl gallows especially aft.

PEAKS.

Wasted knees, breast hooks and frames, with the latter fractured at floor tops, and at toes of beam knees especially in fore peaks.

Rust bound and slack riveting at floor tops and knees.

Washplates and their connections can be badly wasted and are a possible sign of extensive wastage in the tank generally.

Beams and bulkhead plating in way of tunnel escape in after peaks.

Tank top plating especially in way of heaters in the accommodation above; the deck composition is often cracked.

D.B. TANKS.

Margin connections especially at end tanks. (Ore carrying vessels especially susceptible).

Floors and keelsons in E & B room tanks, and for a few spaces forward and aft but especially immediately under boilers, engines and thrust seatings. Condition of reverse frame joggles gives good indication.

Under engines it may be found advisable to fit additional new welded intercostal girders.

Built-in sea inlet boxes.

Ballast pipe lines (underside).

Pan heads of rivets under machinery tank top and quite often in bottom shell badly wasted away when hammered with testing hammer.

With McIntyre tanks (seldom met now) grooving, and fracturing of tank top plating, along fore and aft girder heels and girder connecting lugs to floor tops wasted and slack.

Divisional W.T. floors especially at tops.

Striking plates under sounding pipes and especially if broken sounding rods left standing at bottom of pipes.

HOLDS AND TWEEN DECKS.

Rust drawn riveting in frame brackets, beam knees and stringers.

Frames at cement chocks.

Tween deck plating around hatchways, usually at ends (weather).

Similarly girder face flanges and rider plates have been found badly wasted where coaming slotted for through beams at hatch corners (weather).

In way of portable fresh water tanks and spare propellers, etc.

Shell locally. Air pipes where close to shell where coal and dirt can only be cleaned with difficulty.

Air pipes at tops especially where screwed couplings fitted.

Tunnel side plating (upper strake) where forming boundary of tunnel wing tanks.

Margin plates at tops of frame bracket connections, and also at average bilge drainage water level.

Tank top at after ends of holds in wings.

W.T. bulkheads at ends of machinery spaces especially under stools, etc., and also where forming boundary of coal bunker spaces.

Collision bulkhead in way of chain locker.

Tween deck bulkheads at wings, lower corners.

Tunnel side and tunnel recess bulkhead plating at bottom (weather).

Tunnel recess top side plating especially where cambered.

Ventilator trunks to deep tanks and tunnel recesses.

Upper deck plating within superstructures at doorways.

Bridge deck plating at accommodation and especially if tween deck coal bunker spaces below.

Coal Bunker Spaces.

Generally, but especially, saddlebacks, shoots and adjacent plating and deck plating.

Boundary bulkheading, frames, beams in way hatchways and airpipes.

Girder ends and adjacent casing plating in tween decks.

E. & B. Spaces.

Tank top plating under boilers especially immediately forward of stools and also adjacent frame space or two in engine room.

Under built-up main engine seatings and under pump and condenser seatings.

Underside of ash shoots.

Pan heads of shell rivets in boiler room bilges can be badly wasted.

Decks.

Adjacent to chain cable pipes and chain locker top.

Between hatchways.

Where water lodges at butt overlaps.

In W.C.'s adjacent to pans and heaters.

Under wood decks especially where uneven and tending to lift and adjacent to steam pipes.

At galley and accommodation spaces situated over machinery spaces.

Houses.

At portlights either immediately below or at toe of foundation angle. (*Note*:—If hole for drainage found to have been drilled in wood casing under portlight quite possible wastage under.)

Rust drawn riveting very often evident, and especially with flush riveting so often used in houses.

Casings.

Side plating at steam pipes, and at galley coal bunker box.

Tops especially around boiler casing and ventilator coamings.

Galley bulkhead behind range.

Chain Cable Pipes.

On inclined underside.

Rudder Stock.

Where trunk very small and in way of deck bearing.

Rudder trunk plating.

Rudder Mainpiece.

Adjacent to arms especially about middle depth of rudder.

Steering Gear Leads.

Pins, bushes and chain nips where insufficient lubrication, and rods for grooving corrosion.

Hatchways.

Coamings in way steam pipes, and also where electric leads have been led along coamings.

Various hatch fittings especially battens.

Hand Pump Forward.

Holes sometimes found drilled at after end of tank top to drain into fore peak tank. No hand pump or same badly frozen up.

Masts.

Immediately above riveted overlaps, mainly at after side (condensation and leakage down inside especially where topmast telescopes), and also at bottom inside.

At closely fitted electric cables.

Mainmast where smoke fumes from funnel may result in considerable perforation hidden under paint and grime.

Oil Tankers.

In the tanks. Where heavy oils are carried special care as regards bottom shell and rivet corrosion and pitting, especially under centre tank hatchways.

With light spirit cargoes all the upper structure can be suspect.

MR. P. J. N. JISKOOT, ROTTERDAM

Dialogue

Surveyor :

You, ancient ship, built long ago,
Have stood the test of time, and now
You've brought the freights from East to West,
From North and South; you've done your best.
So many years you've cleft the waters,
So many men have lodged your quarters,
So many times your crankshafts turned,
And large amounts of fuel burned
In your furnaces, with roaring sound,
To gain the ports to which you're bound.
I like your form, your masts, your funnel
Your fore and afters, buckled tunnel,
Your sluice valves and your slender pillars,
Your quadrants, steering chains and tillers,
Your dirty bunkers "Cleaned" for my inspection
Your sup'rintendent's never raised objection
To fitting new material, erecting still more stages
Though he's counted with alarm the bill of many pages.
But . . . after all (I hope it won't surprise you)
I must admit that in the end, I do a bit despise you.
A nuisance, that is all you are, next time you'll not deceive me
But exposed will be from stem to stern and then be cured, believe me.

Very Old Ship :

So many times I've said my prayers
Beseeching that the Lloyd's Surveyors
Be merciful; adding with a stammer
"Don't let them use too big a hammer."
Those chipping tools, Oh! how I hate them,
And cutting torches, cursed who made them.
You awful O's, in bright white paint
Crossed by two lines, make me feel faint.
How I detest the shame of dry docks.
Some Ship Surveyors are merely Shylocks
With heavy feet they tread my deck
"Cut here, drill there, look at that crack."
Then, touch my nakedness, slap my bottom,
My ribs, my skin and burn and blot 'em,
But still . . . I know it's for my good
All that I ask is, don't be rude,
Just make me good for four years more
And treat me wisely, I implore.

MR. M. P. JONKER, ROTTERDAM (Retired)

Cleaning, scaling and even painting of bottom and side plating in dry dock, as well as cleaning, scaling and painting of the internal parts sometimes leaves much to be desired. There are Superintendents and Owners who are not so particular and who are of opinion that scaling, though very good in itself, costs time and money. Therefore they don't scale and prefer to paint the rust; that is sufficient, saves money, gives satisfaction, looks good for the present and is a good preservation for the rust.

Ships treated in such way, after twenty years of service may be called "very old ships." They give the classification Surveyor many difficulties at special surveys and require a lot of experience and insight.

A first recommendation, whilst in dry dock, may be for the shell plating to be scaled for examination and gives cause for the first discussion with the Owner's Representative.

"It would be a good thing but it means an expensive job and there is no time, the yard has no labourers, etc., etc." and the result is that to begin with the seams and butts only will be scaled.

The Surveyor meantime has mentally noted the worst places and when stages are being erected or trestles placed, he starts to hammer-test the plates locally, doing a lot of scaling himself. If the plate sounds thin the Surveyor must often ask for a test hole to be drilled in order to convince the Superintendent that the plate really requires renewal and this helps him to reach a decision about the scaling demanded.

The Surveyor should also at that time examine the shell plating internally and particularly along the heel of frames and stringer lugs, because the shell plating may look good outside but be very bad inside. All this should be ascertained before the ship leaves dry dock, otherwise the Surveyor may find himself in difficulties later on.

The internal examination should include shell plating and frames in way of cement chocks, shell plating in way of boundary bars, bulkhead wing plates, margin plates, etc., because if later on renewals are found necessary, leakage may occur.

It is wise to have a complete specification made of the internals before the ship goes into dry dock, but this may again necessitate a lot of cleaning and scaling and we hear the same song about costs, delay, etc.

"Now look, Mr. Surveyor, if you would be so kind to examine the ship inside before we have finished all the scaling and even right away now because the ship is not so dirty (but both men know this is not true), we could make a preliminary repair specification. That would be a great help and save a lot of time."

The Surveyor often is willing enough, giving the warning, however, that what is found later on will have to be renewed just the same.

Everything is fine and Mr. Lloyd is very kind but as soon as, after the cleaning and scaling, the Surveyor starts his final inspection then he hears : "I thought, Mr. Surveyor, that you had given me a complete list of the repairs and now you ask me for still more; that is not a nice thing to do to me. The ship must sail, etc., etc."

The Surveyor thinks and sometimes says aloud that this is the last time and that he never again will be helpful if that is what it means, but the next ship, when they ask the same question, the Surveyor probably will do it again, notwithstanding the trouble.

MR. A. M. KENNEDY, LIVERPOOL

When the late war started, many old ships, which were ear-marked for the scrap-heap, had to be repaired to keep them running for use in the War. These cases provided a good lesson on the subject.

Longitudinal Strength.

First, the longitudinal strength items, such as decks and shell, were examined and their strength estimated after drilling, and then compared with the strength of the original material, as given on the plans.

If the sectional area of the deck plating was found to be reduced then it was usually easiest to restore the original area by renewing, of increased thickness, the centre strake of three (the usual number of deck strakes of plating abreast a hatchway), always provided that the two other strakes had a suitable thickness. Sometimes, as an alternative to the renewal of the centre strake, it may be more convenient to fit a doubling plate on the top of the stringer plate, of the thickness necessary to restore the sectional area of deck material.

Local Repairs of Plates and Sections.

If a plain angle, say in a built frame, requires renewal because of a thin web (the shell connection flange of the frame being still good), then the web can be cut out and a new slab plate of the necessary thickness veed on edge, fitted and electrically welded to the original shell flange. This method obviates having to cut out the shell rivets.

Where portions of plate require renewal, "veed" butts can be arranged and electrically welded, same being finally ground flush, thus making the completed job look like the original.

For instance, where the leading edge of a stem shell plate is worn, usually in the vicinity of the lower curve, a veed cut can be made between the two rows of stem rivets and the forward worn portion renewed and electrically welded in position. This method of repair gives a more sightly job than the old repair of fitting a shoe plate around the stem.

Sternframes.

At sternframes fracture is becoming too common, in my opinion, at the radiused after edge of the lowest shell plate on the propeller post, usually the result of too much caulking and undercutting by subsequent electric welding. When faced with a job where too much caulking has been done previously, try and avoid the use of electric welding, which often results in undercutting of the sternframe with a resultant crack or fracture. If one cannot avoid welding, then taper it off gradually over a length of 2½ in.

A method of repair, often adopted for a ship which has developed large fractures in the sternframe, is to vee out and electrically weld them and, in addition, to fit 1¼ in. side slabs, with 1 in. cover and 1¼ in. base plates.

Corrosion.

With regard to corrosion of steel material, major causes are salt water, condensation on the inner surfaces of material in holds, especially on horizontal, or nearly horizontal surfaces of shell plating, such as at the ends of ships at the heels of framing, where grooving can often be found, also humidity in engine and boiler spaces where extremes of temperature are common.

An example will illustrate these points: In an old cargo ship, about 400 feet in length, a steam pipe from the boilers to the steering engine in the Poop space was carried along the shaft tunnel to its after end, thence up the vertical escape trunk into the steering compartment. The tunnel acted like a hot air duct, causing great heating of the steel double bottom tank top plating, centre girder and keel plate and floor material underneath. This material showed great depreciation. It was interesting to notice that the double bottom material immediately under the cargo hold, that is, clear of the tunnel, was in quite good condition, because it had not been subjected to such extremes of heat and cold as the material immediately under the tunnel. Consequently all the steel material for the full length of the tunnel, that is, double bottom tank top, centre girder, floor ends (about six feet each side of centre girder), and the keel plates, required renewal together with connections.

Similar effects can sometimes be seen where a hot and cold water galley scupper discharges, causing severer corrosion to the shell plating than that normally caused by a cold water discharge from an ordinary deck scupper.

Double Bottom Tanks.

During surveys it is not uncommon to find slack rivets in the intercostal flanges of the floor angle connections in the vicinity of the sloping tank top at the ends of the machinery space, and these slack rivets should be renewed. Always carefully examine such places.

Steel material is not so much affected, as a rule, by ordinary fuel oil, as by diesel oil which causes wastage of rivet heads in shell frames in way of the keel strake and in the keel landings

and, sometimes, affects similar items outboard of intercostal girders. The inner skin of the shell plating at the keel and garboard strakes often shows "half-crown" areas of pitting. The above defects are due to the "rise of floor" which causes drainage to the lowest points where a gradual accumulation of emulsified oil is trapped, the constituents of which attack the steel. The affected rivets usually require to be renewed and the plate "half-crown" areas electrically welded. As the above-mentioned defects have required attention at a first special survey, where diesel oil had been carried, special attention should be paid to such tanks in old ships.

Deep Tanks and Peak Tanks.

Cases are often noted of slack rivets in tank top beam knees, caused by the slinging of slack water or oil up into the corners. Sometimes the slack rivets are renewed, only to be again found slack after a voyage or two.

The best remedy is to electrically weld the knee plate edges to the adjoining frames and beams will take the stress off the rivets at the highly stressed points. In peak tanks, slack rivets, if any, are usually found in the frame to floor on one side only, and are usually due to "panting." The rivet holes in such cases may require reamering out a size larger and reriveting.

Steel Masts.

The butts of masts are usually constructed with the upper plate outside—but the opposite construction is preferable for the following reasons: Quite a number of masts of the orthodox construction have failed because of an horizontal groove of corrosion inside the outer plate at the butt lap of the inner, causing final fracture and mast buckling. The corrosion is caused by water running down the inside of the mast and lodging on the upward looking plate edge of the butt lap.

If there is a telescopic top mast a great deal of water leaks down into the main mast from the joint, over a number of years. Obviously from this point of view it is better to have the upper plates of the butt on the inside. If the Surveyor observes steel pipes (conduits) carrying wires to mast head lights, he should ask that a portion be prised off from the mast, as corrosion often collects behind, even when the mast appears well painted. One mast, carrying a 25-ton derrick, was found to be split vertically, adjacent to a landing behind the conduit, from the derrick table up to the cross trees, and required major plate renewals after dismantling. Sometimes the handiest form of repair—if renewals are not required—is the fitting of external doublings veed on edges and electrically welded there and also fillet welded in body slots to the mast. This method is often useful for temporary repairs. Such doubling plate repairs can also be used for repairs to derricks.

Economy of Repairs Through Rearrangement of Design.

As it is sometimes necessary for an Owner to keep an old ship running for a year or two this problem can be dealt with as shown in the following two war-time cases. The first ship was of an insulated type for the carriage of meat cargoes. She was about 27 years old when the war started and probably the Owner intended to scrap her when the next special survey fell due. However, the war intervened and the Classification Authority was instructed to recommend the necessary repairs and renewals to keep her in service.

The ship was 430 ft. b.p., having three steel decks. Upon examination the 2nd and 3rd decks were found to be thin in the coal bunkers. The Surveyor decided to recommend that the weather deck, which was in averagely good condition, be fitted with enough new doubling material to "straddle" over the two worn coal bunker decks below and thus restore the ship's longitudinal strength by practically making her a "one decker" amidships. Accordingly ·62 in. thick doubling plates were fitted extending for about 60 feet fore and aft above the coal bunkers. In addition, a number of frames and beams were renewed on account of transverse strength.

The above method was slightly varied in the second ship, a vessel 37 years old, subsequent to damage caused by enemy action. The ship had been under water for 9 months.

After lifting, repairs to the damaged portion and to the vessel generally, were recommended to enable her to be classed with the British Corporation. The vessel was 206 ft. 6 in. b.p., with two steel decks. Because of the 2nd deck forward having been badly ruptured by a bomb explosion, the ruptured plating and portions of 2nd deck beams were cut out, leaving only twin

beams and deck plating at the original Nos. 1 and 2 hatch ends, and at the collision and after bulkheads of the forward hold, also leaving the original 42 in. wide stringer, beams and brackets in way all round the forward hold. The above twin beams and the new hatch-end beams at the weather deck hatches were supported by new pillars. Such alterations were made to the top (freeboard) deck, that the new modified design was a "one decker" forward and a "two decker" aft (the latter part being as originally).

INTERIM CERTIFICATES.

Finally, a word or two may be said regarding Interim Certificates. It is well for a Surveyor to remember that he is not only responsible to his Committee, but can be called to account in Courts of Law. Therefore, in old ships especially, his temporary or permanent repair recommendations must be carefully thought out after as exhaustive an examination as possible. In most cases temporary repairs of some sort are necessary, but if he thinks that the ship is seaworthy without any such repairs, he should be very sure of his facts before so deciding, for Judges are prone to ask in Courts of Law "What repairs did you recommend?" Young Surveyors are well advised to be definite in their final recommendations, and not "pass the buck" to another colleague by recommeding a further examination which might not be necessary because the Surveyor had probably been able to make a more extensive survey, and assess the damage better than is usually possible for a colleague at a subsequent date where time may be short.

MR. A. J. KRAAYENBRINK, ROTTERDAM

When repairing very old ships two different aspects have to be considered: Strength and tightness. To be able to secure strength it is necessary for the Surveyor, as a good start of the Special Survey, to investigate how the strength-members of the vessel are constructed. Original drawings, if available, can not always be trusted. "Plans as built" were not customary half a century ago and besides that previous repairs may have involved important alterations in the structure. To enable the yard to make a quick start, this first examination can be combined with making a preliminary recommendation for repairs. It is of importance, however, to make clear to the parties who are financially interested in the job that this recommendation is but the first word.

It is sometimes better to leave intact some strength-member, which is just on the margin, than to renew it and leave attached parts of equal importance but just satisfactory, untouched. The new part is considerably less flexible than the old parts which leads to overstraining of the old parts, therefore, strength-members should rather be renewed rigorously or be left intact. If the condition is such that in any case some parts have to be renewed while adjoining parts are acceptable, repairs must "taper off" to places where stresses are less. This can generally be accomplished by renewing the worst parts and doubling or stiffening adjoining parts up to the region where stresses are low or where the condition of the material is quite satisfactory.

Tightness needs equal attention. It is here that the Surveyor runs much more risk, because here every part of the hull is involved. How is one to convince a Shipowner that the whole ship has to be chipped, inside and outside, if the yard has not sufficient people to do it? Intuition and good luck are very important for the Surveyor in this work (may the angels sit on his shoulders). Generally it is clear enough where repairs have to be started, but it is difficult to predict where the end will be. Parts which are satisfactory as long as they are left in place, sometimes fall to pieces when new material is riveted to them. Renewing is not always the best solution in old ships. Mending, if done in the proper way, is often much better for all parts concerned.

It is very important for the Surveyor to co-operate in good friendship with foremen and workmen. This leads to exchange of experience. Many of these people are experts in mending. Generally they are so proud of their work that they have no secrets from the Surveyor if approached in the proper way, and are very thankful if the Surveyor finds time to fill up gaps in their knowledge of shipbuilding.

Notwithstanding a thorough Survey of the vessel, often serious defects show up in the very last minute to the great disappointment of every one concerned. There is still the possibility that something may be overlooked and may give trouble when the ship is sailing again. Old ships need more than normal attention at normal dry docking between Special Surveys. The question is sometimes raised whether a four years interval for Special Surveys is too long for these ships.

A nicely cemented bilge sometimes hides very bad shell- and margin-plates. It is good to remove even perfect looking cement here and there for a check. On very old iron, rust forms in big patches which adhere so strongly to the plates that a big blow is needed to remove it. It is therefore that the use of revolving chipping hammers should be discouraged. A heavy pneumatic hammer with a sharp chisel will do much better.

In many repair yards the procedure of injecting whitelead or some other putty to stop leakages or to fill up the space between a doubling and an old plate, is done in an old fashioned way which takes so much time it is often useless. Instead of the small injection gun which contains only half a pint of putty and which necessitates drilling and tapping of a hole, good use can be made of instruments as used for greasing autocars. The smaller ones for stopping leakages in tanks, etc., need only drilling of a $\frac{1}{8}$ in. hole and no tapping. In confined spaces this is of great advantage. For filling up spaces under doubling plates, which sometimes require buckets of putty, good use can be made of the foot operated grease gun, which pumps in a gallon of putty in one operation.

Welding of wrought iron sternframes, rudder mainpieces, etc., should not be considered satisfactory. Cracks in these parts, which are sometimes of no importance, become of real importance after welding up. Real bad defects require, of course, renewals but reinforcement with plates and sections is often as effective.

In the old days doubling plates were quite common in new ships. Sheerstrakes and deck-stringers were sometimes doubled over a great length. Local repairs of such parts by doubling again, though not always objectionable, is not very effective, as the rivets which keep all these plates together become too long. Deck plates under floor covering are often found doubled from the underside and even redoubled and doubled again. There comes, however, a time when it is necessary to take away these bunches of doublers and fit something better. In general doubling plates should only be fitted if the surrounding material is strong enough to make a good connection possible. This is often overlooked. It is sometimes too easily decided to fit a doubler while further examination shows later that renewals are necessary.

Panels of plating like bulkheads, floors, keelsons, webs, stringers, of which the thickness is reduced to some extent, but which are too good to be renewed, can with advantage be stiffened. In cases where this stiffening is meant only to compensate a reduced thickness of the panel, crosswise or diagonal stiffening is sometimes preferable.

During repairs of shell plating it is difficult to make a proper fit of new material to old material, because the rust falls out from between the parts. Special care should however be taken to obtain proper contact in way of the rivets. Any gap between the two parts in way of the rivet leads inevitably to a severe leak when the vessel touches a quay wall in that place. Small wedges fitted in way, and backwelded to keep them in place, serve well to prevent disturbance. If temporary repairs have to be done to old ships after damage it is worth considering whether to make them such that they can be considered later as permanent. It is no use to aim at making old ships free from indents or patches at a Special Survey. A Shipowner who is willing to have permanent repairs done at a Special Survey, is not always aware of the grave consequences. Proper advice in time can save him a lot of money and trouble.

In old ships rivets are often found of which the heads are entirely gone. Removal of such rivets however is by no means easy. The conical form of the rivet holes which were originally punched but not reamered, keeps them in place. The present day cylindrical rivet holes, nicely drilled and reamered, seem not to be superior to the old ones in every respect. Welding of new material to very old material, if done with the necessary care, can give satisfactory results. It should however be restricted to patching and not be used in strength members.

MR. C. R. ROWCLIFFE, VALPARAISO

The survey of very old ships, that is to say, vessels of about 30 years of age and over, requires more than the usual amount of patience and diplomacy, due, invariably, to two main reasons :—

1. The vessel is generally being kept running by the Owners until such time as a new vessel is obtained and, therefore, the very minimum of money for repairs is available; or
2. The vessel is owned by a Company which has bought the vessel or vessels at scrap price and has very little capital to spend on repairs.

It is customary at Valparaiso to make plans of all major repairs carried out, so that if I have carried out a previous special survey at this port or big damage repairs, the parts likely to require renewing at the survey now being held can readily be seen and inspected first so that repairs can be started.

When commencing the survey the weather decks and coamings should be surveyed, if possible, the first day, as if left till later it is almost impossible to carry out an efficient examination due to their being littered. Before starting your tour of decks, your retinue of men should be collected, consisting of burner, for burning test holes, with a helper to go below deck to remove paint, scale, etc., and a man with a pot of white paint and a brush to mark thicknesses on deck as taken. Ones back is considerably saved if the sounding of decks is done with a long tommy bar, and it is surprising how quickly one gets accustomed to gauging, by the feel and sound, the approximate thickness.

If the deck is considered generally wasted, then it is advisable to have test holes in every plate, study the whole picture, and then make the necessary recommendations.

The most troublesome place and where generally repairs are necessary, is at the hatchway ends between coaming and deck houses. The plating inside the deck houses is generally found good and to remove wood lining, flooring, furniture, etc., is a long and costly job. One is sometimes fortunate in being able to cut the wood lining up, say 1–2 ft. from the deck, crop and remove casing plate at bottom and remove part flooring, then deck plates can be cropped at good material and renewed out to the hatch coaming, electrically welding the butts. It is necessary to remove the hatch coaming deck angle which more often than not requires renewing due to wastage of deck flange.

Hatch Coamings.

Wastage of hatch coamings can be expected in one or all three of the following places :—

1. In way of steam pipes.
2. In line with top edge of horizontal stiffener and in way of cleats.
3. In bottom flange of coaming plate in hold.

If the coaming is found wasted locally in way of steam pipe flanges only, which it so often is, then building up the wasted area by electric welding can be considered satisfactory.

If the wastage is general and in way of steam pipes only, then the coaming plate should be cropped just below the deck and top part renewed, the join of plate being electrically welded.

The wastage in way of the top edge of horizontal stiffener and/or hatch cleats is generally such that building up with electric welding is satisfactory, but sometimes cropping of the plating and renewing the top half has to be resorted to.

The wastage of the flange of coaming plate in hold has in my experience been confined to colliers and here again, if the coaming plate above deck is found satisfactory, the plate can be cropped at about deck level and lower flanged part renewed, the join being electrically welded.

Tween Decks.

Shelter and lower tween decks in way of holds are generally found satisfactory, but special attention should be paid to stringer plates and frames in way of cement chocks where considerable local corrosion is likely to be found, and this also applies to the shell plate in way.

The cropping of stringer plate, half width, and renewing the outboard wasted portion, electrically welding the seam, is generally found easier due to the seam of stringer plate being an in run of plating.

If the wasted frames are through-frames, then cropping the frame at centre of beam knee and about 1 ft. above cement chock is generally found sufficient. The butts of the new piece of frame being electrically welded.

If frames are short frames riveted to main frames below deck, then cropping the frame about 1 ft. above cement chock, and renewing the lower portion with electrically welded butt, is generally carried out.

In bridge and tween deck bunkers, the foregoing wastages are usually of a more general nature and the renewal of the whole stringer plate and frame is necessary.

The wastage on the shell plate in way of cement chocks has never been found more than could be safely built up by electric welding.

Decks below accommodation in passenger or crew spaces are a source of worry. If, however, on examination from below, rust spots are found, then one is justified in asking for the deck covering to be lifted, when the full extent of wastage can be ascertained.

The cost of carpentry work, etc., for removals is generally more than the cost of the actual deck repairs.

The removal of portions of the deck covering for examination of the deck below often shows a considerable amount of rust, yet when plate thicknesses are taken they may be found more or less satisfactory.

The wastage of decks in way of bathrooms, etc., is common and can generally be dealt with by cropping and locally renewing the decks to one frame space each side out of the affected area without having to do much dismantling, butts being electrically welded.

Tank Tops.

Repairs to wasted tank top plates calls for no special comment as repairs are easy to deal with. The most likely places to find wastage are in bunkers, under boilers and under attached pumps of reciprocating engines.

Tank margin plates can be a source of trouble and the full extent of wastage should be ascertained before deciding on repairs necessary.

It is quite common to find the margin plate cracked through at the top of the bilge bracket angle connection. If on testing the plate away from the fractures the thickness is found satisfactory, small electrically welded doublers 12 in. wide may be welded to edge of tank top plate and to margin angles and extending down 3 in. to 4 in. after first welding the fractures.

The top half of margin plates is sometimes found wasted, the lower half being more or less original thickness. Considerable removals are necessary to carry out effective repairs as the margin plate is the lower plate at the tank top seam.

If the bilge brackets have not been previously renewed, then it is generally found that they also require renewing, which only leaves the margin bracket angles for removal in order to enable the margin plate to be cropped at half depth for renewal of top half. It is considered advisable also to renew the angles to make a reliable job and special care should be taken when re-fitting these angles to see that the welding and slight difference in thicknesses of new and old plates is ground reasonably level in way of angles.

Special care should be taken in the examination of tank margin plates in way of bilge suctions, which are very often found locally wasted. The fitting of a doubling plate for one frame space is all that is generally necessary.

Double Bottom Tanks.

Major repairs to the internals of double bottom tanks are generally found to be necessary, under boilers, the first few frame spaces forward of the stokehold bulkhead and under the tunnel (specially when the steering gear steam pipes run through tunnel).

If floors have been found generally wasted and on the border line of renewal thickness and vertical stiffeners have been recommended, care should be taken to see that the stiffeners are connected to the top and botom angles either by rivets or welding to the toes.

Floor angle connections to margin plates in No. 1 double bottom tank are sometimes found fractured due to mechanical grooving caused by the vessel working in that vicinity. The question of adding additional strength is often discussed but, in my opinion (unless the vessel is comparatively new), the renewal of the angles is all that is desirable.

Shell Plates.

The forward three plates in the A, B, C, D and E strakes of old vessels, if not already renewed, generally require to be dealt with. The No. 1 plates in the A and B strakes are shaped plates longitudinally and vertically with flange connections to stem. The shaping of these plates is a difficult and highly skilled job, and when one is in difficulty, the welding of the flanged piece of flat plate for stem bar connection, to the remainder of the shaped plate, in place, has proved satisfactory.

Fractures in shell plates in way of bulkhead bracket shell angle connection in the space between the end of angle and frame, are common

in old ships. The removal of the angle, electric welding of the fracture, the fitting of a tee bar, in place of the angle, fitted up to and electric welding to the frame forming a doubler over the fracture makes a sound repair. The rivet holes in the shell plate should be filled up by electric welding, and the tee bar should be welded to the shell, and the bracket riveted to the tee bar.

MR. J. RUNDLE, BOMBAY

Very often shell plates that have been satisfactorily drill tested have to be condemned. Test holes are always made between frames where the work of chipping and painting is easily done. It is not so easy to get a chipping hammer into places such as the shell plating immediately below tween decks, at the ends of panting stringer shell lugs and at the heels of frames, especially at the forward and aft ends of the vessel. The rust grows with the assistance of condensation running down the internal plate surfaces. Amidships, condensation runs down vertically, or almost so, depending on trim, but at the forward and aft ends of the vessel, the shape of the hull causes condensation to run down against the sides of the frames. As the upper condensation runs down it gathers more water from the condensation on the lower areas and this water running down the side of the frame also has to pass through the opening at the snipe of any panting stringer web plates in way.

Corrosion therefore may confidently be expected at the following places forward in order of intensity :—

1. On the shell plating in way of the snipes of the panting stringer web plates.
2. On the shell plating in way of the forward edge of the frame.
3. On the shell plating in way of shell stringer angle bars and on the angle bars.
4. In between the shell and the stringer angle bars, causing springing and bending of the angle bar between the rivets, leading eventually to broken rivets between the shell and the angle bar.

In the case of 1, the corrosion found is in the form of a lump and would pass as being part of the solid plate. It is easily found, however, by shining the electric torch sideways or up and down the surface of the plate being inspected. Using a torch in this way and looking for shadows is more effective than shining the light on to the surface. These lumps of corrosion are very hard and when eventually removed, the hole left behind in the shell plate is usually deep. In passing, leaks have occurred by such lumps cracking off by outside pressure such as is caused by a barge coming alongside, exposing a thin area of shell plate.

When such corrosion is found, it is usually accompanied by grooving of the shell plate at the heel of that frame, above or below, or by grooving of the shell plate in way of the shell stringer angle bar and in such cases the plate requires renewal.

Where the corrosion is local in way of a panting stringer shell lug, an effective repair can be made by an internal strip doubler frame to frame.

Very often with an old ship we are called to look at a "hole" in the ship's side. Again, this "hole" is never half way between frames. It will mostly be found at the heel of a frame, the line of tween deck or the line of a fore and aft stringer and it is usually not a hole but a line fracture caused by a combination of wastage due to rust at the awkward corner, plus the bending stresses which are at a maximum at the point of fixation.

At the forward end of No. 1 lower hold, always remove all the cement chocks between frames at the top of the bilge brackets. There is usually much wastage there. This also applies to cement chocks between frames in tween decks.

On the fore peak bulkhead, where panting stringers are attached by brackets, vertical grooving sometimes occurs at the toe of the bracket. A good repair can be made by welding the grooving and adding an extension to the bracket angle bar.

At the aft end of an old ship it is usual to find thin plates and grooving at the heels of frames high up in way of and forward of the tunnel recess.

Wherever frames are joggled there is usually much corrosion under the joggled parts of the frames. If the gap under the joggle is found filled with rust the frame should be cropped and removed for examination of the plate in way as a sample.

Corrosion is often found internally on the shell plating just above the upper edges of inside strakes, where condensation lies.

On deck stringer plates the thinnest places are found at the toe of the stringer bar about two to three inches away from the toe of the bar, where the edge of drainage water and air meet each other. The same applies to joggled deck plates.

The condition of masts on old ships, especially those with mast capping consisting of wood wedges covered by canvas where the wood top mast fits into the lower steel part of the mast, can be most easily found by drilling (usually burning) a hole at the place where most corrosion occurs. This is again where condensation or leakage from the mast capping lies. Riveted masts are usually made with the lower strakes fitting inside the upper strakes and as masts on old ships usually have a rake, water lies on the upper edge of the inside strakes. Drill testing there will give a sure indication. Masts have given way and collapsed here with a thickness of less than $\frac{1}{16}$ in. although the thickness elsewhere was efficient.

MR. W. B. SCHEELINGS, ROTTERDAM

High age of the "Lady" does not necessarily mean that her condition is bad, on the contrary, it often happens that a much younger ship is in a worse condition, in spite of nice coating.

Let us assume that under "Old" the age of the ship is meant : built round 1900.

The question now arises :—"Why is this old ship again submitted for survey." Various replies are possible : The ship is well kept and practically written down, the expected cost of survey repairs will not affect the economy of operating the ship in such a manner that competition with modern ships will be impossible. Taxation often is of great influence, even if survey repairs are high. Prices of new ships are too high and delivery time is too long. The condition of the ship may not be well known, but Owners want to keep her for sentimental reasons. The latter case sometimes has the result that the ship, already under repairs, ends her life at the breaking up yard.

If a ship of the last paragraph is submitted for survey and it appears at the first visit that the condition is poor, the Surveyor should suggest to the Owners to have the ship opened out and prepared for survey before starting repairs in order to have a reliable estimate of the costs. This method saves all parties great difficulties.

The first visit already gives a fairly good impression of the condition and makes it easy to give the right recommendations in order that the ship may again comply with the Rules for the next period. If these recommendations comprise extensive repairs it is advisable to distribute the new material in a proper way and to avoid hard spots as these may give trouble later on. If for instance the sectional area of the deck plating is too much reduced, it is better to renew a complete strake instead of renewing individual plates in various locations. This system is often less expensive too.

Every "Old Lady" has her own freaks. Also their make-ups may be different : rust, cement, bitumastic or paint. The "émail" may be very strong and generally it can be said that the make-ups cannot be trusted.

A recent survey of a very old ship gave such a surprise; the main deck plating abreast boiler casing, when surveying the deck plating from underneath, showed small signs of corrosion in way of the forward bulkheads of deck houses which extended to the stringer plate. After removal of the deck composition it showed that it was not properly adhering to the boundary bar of the deck house bulkhead. It appeared after cleaning that the deck plating was completely corroded through and that the stringer plate had been doing all the work, although itself considerably reduced in thickness.

A similar case was found in a ship where various deck plates had been doubled up to the boundary bar. The doubling plates and the boundary bar gave a hard spot so that the plating between same cracked over the full breadth of the ship except the stringer plates, leaving them to keep the ship together. This example shows that fitting doubling plates requires careful attention, particularly in way of the main structural parts.

That rust can be very strong was shown in a recent case. After removing a layer of hard rust on the shell inside, just behind a bulkhead stiffener, a hole was found of approximately 18 sq. in. The outside plating did not show any indication and looked quite good. The ship must have been sailing for some years with the underwater shell at that spot of rust instead of steel.

Similar situations may occur where the cement in the bilges is no longer adhering to the plating.

If the ship is very old, you will find her noted in the Register Book to be of iron. A survey of such a ship will not give special difficulties but very often serious pitting will be found while the riveting also requires special attention. Welding of new structure to the existing iron structure will always give trouble afterwards and should be avoided.

SUMMARY :

If you have to survey a very "Old Lady,"
Often more in years than you may be,
Looking strong, well coated and nice,
Don't trust her is my strong advice.

She hides all her defects; be alert!
Behind paint, rust, cement and . . . dirt,
Therefore make them chip, scale and clean,
So that everything can be carefully seen.

Be sure she likes strengthening a lot,
However try to avoid a very hard spot;
Be also careful with doubling plates,
A repair she sometimes very much hates.

If being very old, of iron she is,
Following items require your attention, viz. :
Riveting, pitting, while welding, be sure,
Is always for this Lady a very bad cure.

Often you are responsible for something greater,
She ends her life at a scrap merchant's breaker,
Unlucky she was to come your way
A man so hard and unwilling to play.

Therefore treat her with care and be kind,
But keep always the following in mind :
Good must be every rivet, angle and plate
Before you may issue her a clean certificate.

MR. P. H. VAN DER WEEL, ROTTERDAM

There are several points and details essential to the surveying of very old ships.

Not long ago we had what I think would come under the scope of this paper. The ship was about seventy years old. She was not really bad, but the difficulties surrounding her case offered the aspect of our Society being involved in a melancholy situation.

The Owner, at first only a disillusioned man, soon showed bitterness which grew apace with the list of repairs.

But we stuck it out, or rather the Owner did, and when the ship left—with a crew sent over so early they had had plenty of time to learn to speak Dutch—she was in much better shape than when she arrived. In fact she left in a "good and efficient condition" and we reported accordingly to the Committee.

We must preserve the ship's overall strength, not forget that local stresses must be successfully withstood, that loaded she must not only keep afloat in bad weather but carry her cargo safely to its destination.

If the very old ship is a tanker—tankers grow old more quickly than dry cargo ships—then a change in Register Book notation from "Petroleum" to "F.P. above 150° F." may give quite a different aspect to the problem whether a recommendation for extensive renewals is justified.

Likewise in the case of fuel oil a new notation of "Carrying homogeneous cargoes between cofferdams and pumproom" may solve problems.

A Surveyor always willing to help and therefore sometimes a trifle too quick, should be careful not to rush through the early stages of a special survey. Nobody should be left in the dark about your intentions and your arrangements should be clear. Let no undue optimism grow in the mind of the Owner. Your determined yet considerate action will soon make it clear to the Owner that you mean serious business but that his money will not be spent indiscriminately. He still will not like your spending his money, but at least he will appreciate that it is being spent judiciously. You will win his esteem, a most valuable thing to have.

Where scale and rust hinder your judgment, recommend scaling, also the shell plating outside, and inside if needs be. Sometimes the aspect of a landing edge gains by scaling—sometimes not. We recently had a case of thousands and thousands of wasted points of shell rivets, completely hidden by a very heavy and extremely consistent coat of rust.

Do not accept drilling of test holes in shell plates unless both surfaces are accessible and clean. Do not leave gauging to others; whilst it is profitable to vest confidence in others there occur moments and situations when it creates temptation. Do not gauge shell plates from

outside if otherwise possible. The plate may be sound in the middle between frames but along the frames may be almost gone by grooving. In an old passenger ship I found a dozen side shell plates which along the frames gauged ·20″ instead of the ·60″ recently reported and measured in test holes 16 inches away from ours.

If scaling is necessary, particularly along the heels of frames in peaks and bunkers or of stringer angles and stringer lugs, a pneumatic chisel should be used. Don't forget that even a dockhand's scraper may reveal a waste hole in a shell plate you had already passed weeks before.

Make early arrangements about the cutting out of all cement on bottom plating under boilers in single bottom ships, also elsewhere if found started, about the cutting out of cement chocks, all or a representative number and every one that is in poor condition.

A knowledge of the location of renewals from previous special surveys or resulting from damage repairs is useful.

In tankers get stages rigged under the decks in all cargo tanks. Any lito silo deck covering should be suspect and exposure of deck plating underneath lito silo should be done generously, but a preliminary examination underneath the deck is indicated.

The same for galleys, pantries, sculleries, lavatories and when the crew is housed in forecastle, in poop or in one of those old fashioned sunk bridges amidships. Have a good look at the upper ends of hold frames where they pass the deck: they may be wasted by the dozen whilst otherwise looking alright.

Old ships may be built of iron, wholly or partially. Some precaution is necessary when punching out rivets; cracks are easily started, but they do not propagate as easily as in certain mild steels. Wrought iron can show a lot of corrosion and still remain consistent. I have seen serrated landing edges where rivet points projected from an extremely reduced plate thickness, a situation that must have existed for a considerable number of years.

Welding to wrought iron goes quite well, but there should be sufficient stuff left for connection. Wasted rivet heads require repairs but if in doubt about the possible lifetime still left to such rivets it should be borne in mind that the ancient rivets had tapered necks.

It may be that the case has sufficiently important aspects for the Principal Surveyor to join the survey forthwith but if not his visit should be nicely timed and should of course include the examination in dry dock. Not too early because, if the survey is not cut and dried in general, the poor man may have to come again. It may happen that a subtle Owner, after such premature and inevitably superficial visit of the Principal Surveyor, starts saying to the attending Surveyor "Why are you looking round any more for repairs? Your boss has seen the ship and has said she was quite good for her age." Not too late either because one never knows, the Principal may have different views on certain matters of importance.

The question of what should be renewed, what should be strengthened and what can safely be left intact is not simple to answer; several factors are to be considered. Old dry cargo ships had heavier shell plating than more recently built ships whilst narrower spacing of the frames and the presence of side stringers give much smaller plate panels. This is important when considering local as well as overall strength. These panels may be grooved inside along all edges, the frames reduced in thickness, the stringers sometimes a curious assembly of part renewals, part backbars and doublings, part original components, part riveted, part welded. Yet the experienced Ship Surveyors in many cases cannot help thinking that the whole construction, which proved to have stood up to the weardown and fatigue of a ship's long life, is still going strong and may be left undisturbed. No danger for the next four (now practically speaking five) years. This may be the last period of five years of the ship's life, a thought that never occurs to the Surveyor in the case of ships not very old, though often hinted by Superintendents. Should the ship be sold immediately after the certificate is issued the purchaser must feel that he has an efficient ship in spite of her age.

There are cases where the only solution is the wholesale renewal of stringers and frames, of bilge brackets, beams or stiffeners, with or without the plating they support. If the plating is satisfactory but the stiffening deficient then the possibility of compensation should be considered. In such cases (and also when the panel plating requires splitting up in smaller panels) much can be achieved, and cheaply, by fitting

extra stringers made of notched anglebar welded to the plating and to the crossing sections.

As long as there is a sufficient plate thickness left or sufficient stuff to make connections, compensation should have preference because, whilst we know where we start, nobody knows where it will end. What looks and in fact is alright as long as left undisturbed may cause trouble when taken down.

My remarks were meant for my young colleagues. As for my senior colleagues I ask them kindly to consider the following thought that has, rightly or wrongly, occurred to me: Since the last war ships, at special surveys—and, alas, sometimes between—appear to me to be in general more often neglected by the Owner or carelessly surveyed than happened before the war.

PRINTED BY LLOYD'S REGISTER OF SHIPPING,
AT THE SOCIETY'S PRINTING HOUSE, 64, SOUTHWARK STREET,
LONDON, S.E. 1, ENGLAND.

DECEMBER, 1952

PRIVE AND CONFIDENTIAL

Lloyd's Register Staff Association

SESSION 1952-53

PAPER No. 4

The following additional contributions
follow the publication of the Symposium

on

THE SURVEY OF VERY OLD SHIPS

LLOYD'S REGISTER OF SHIPPING,
71, FENCHURCH STREET,
LONDON, E.C.3

The Author of this paper retains the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals

THE SURVEY OF VERY OLD SHIPS

The following additional contributions were sent in after the paper had been published

N. M. KISSELL

Mr. D. S. Forsyth, Gothenburg, has covered the ground, or rather the ship, pretty thoroughly. To his last paragraph may I add that in old tankers special care should be taken not only in way of strums but in line with them, as the effect of the suction on the plates can be very severe and not always noticed from the inside of the tanks.

In a tanker with port and starboard cargo tanks and wing summer tanks, the A strakes were drilled close to the keel plate and found averaging from 5 to 8 mm. in thickness for the full length of the tanks, the original plate thickness being 15 mm.

All the cargo tanks were affected and repaired by doublers extending over the full length of the nine cargo tanks (port and starboard). I should add that this tanker was longitudinally framed.

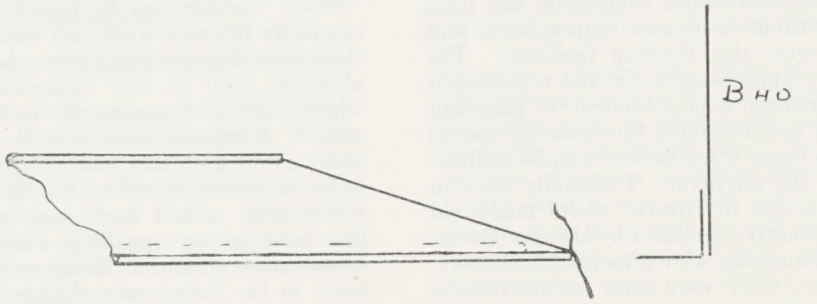
In a tanker, cracks about 10 in. long were found at the toe of the bottom longitudinal frames which terminated about $1\frac{1}{2}$ in. from the forward bulkhead boundary angle. It was noted that the longitudinals were cut well back as shown in the sketch, which may or may not be good practice. In this case No. 9 port and No. 8 starboard cargo tanks D strakes were affected. The plates on either side of the D strakes were doubled in way of the bulkhead, but apparently this did not prevent a certain amount of fatigue taking place at the toe of the longitudinals on D strake.

W. RENNIE

These remarks are intended for young colleagues not yet fully experienced in such inspections and without service in ports abroad.

Protect your health by being properly clothed and equipped for what is going to be an arduous and dirty job, exposed to wide variations of bodily temperatures. An elastic padded knee pad enables you to drop on one knee without discomfort when crawling through double bottom tanks. You require for reference a midship section or original scantlings particular sheet. Reserve a special note-book or a section of your current book, as it facilitates the reporting of the case upon completion. Itemise in detail all parts to be examined and tested to rule requirements for the special survey, circle the item when passed and see at a glance the status of the survey. Apart from the usual tools, plate gauge, standard taper gauge, calipers, etc., it is an advantage to have double outside calipers for rough-checking the thickness of side frame web thickness, wall thickness of valve chests and the like.

The testing hammer is the surveyor's most valuable adjunct. Decide on a suitable type of hammer, use it at all times, and as you become accustomed to its feel you can gauge approximate thickness of plating with confidence. For some twenty-five years I have used a head of fair weight about 7 in. long with a round ball at one end and a 1-in.-wide rounded vee at the other end, with a shaft some 13 in. long



secured by a steel wedge retained in position by a wood screw (a loose head being misleading). Any renewals or replacements are to the same dimensions. When sounding a plate (free locally of scale) heavy hammering is quite unnecessary, except to pierce the plate. Lightly touch the plate with a few fingers and feel for the reverberation of the plate when sounding in the vicinity of a doubtful area.

Mr. P. F. Balfour and Mr. C. R. Rowcliffe have both referred to sounding of deck plating with a tommy bar as the most convenient manner of detecting unduly worn plates. With a little experience and proper handling it is most reliable. I prefer a straight bar with a rounded base about 2 in. diameter by some 4 ft. long. First get the feel of the bar by progressively dropping it about 12 in. to 15 in. on a solid spot, such as the base of a bollard, the deck gunwale bar in way of a beam, stringer plate at a beam, stringer plating in the middle of the beam spacing, then the adjacent strake of deck plating, which is relatively thinner. Hold the bar very lightly, merely guiding it on the rebound, and judge by feel, sound and rebound. Drop it between your feet in doubtful areas, and then try denting the plate with a few heavy blows. Needless to add, you must handle the bar personally. It is equally effective on tank top plating provided the double bottom tank is not under pressure, and the bar can be used for prodding the underside of decks in way of deck composition, cement, tilling, etc., where rust spots are present.

The foregoing remarks appear very elementary; yet one observes many persons banging away at ships' plating without a clear understanding of the technique involved.

At many ports abroad the surveyor is confronted with the problem of a vessel being submitted for special survey with all interested parties leaning on him very heavily for guidance and direction. A small contractor has been engaged without adequate supervisors and without private dry docking facilities. The owners, very apprehensive, are not represented by an experienced superintendent to plan and organise the preparation of the vessel for special survey, also many other factors may be militating against the Surveyor. I specially have in mind my service in Greece, where many old ships then recently purchased by the new Owner during the depression were presented for survey. In most cases there were some serious defects to be discovered, the sooner the better, without waiting for parts to be thoroughly scaled, cleaned and opened up for survey.

In the case of this type or most other special surveys it is in the Owners' interests for the Surveyor to carry out a preliminary general examination of the vessel as a commencement and ascertain the general condition and any obvious defects. Make prompt recommendations for the necessary scaling of the structure, clearing of spaces, amount of ceiling, lining, sheathing, cement and rust to be removed, press for the opening up first of peak tanks and double bottom tanks (way of machinery spaces) and other compartments and parts where serious wastage can be generally anticipated. Enquire what bunkers are on board and discuss most expeditious manner of clearing the tanks or bunker spaces for examination and test, lay off the shell drillings (if due for drilling) of the plating above the light draft without waiting for docking and underwater drillings at perhaps some later date, sound the decks and tank top plating and check condition of bilge structure in way of cargo holds. With a good early impression of the ship's condition repairs and renewals can be recommended without delay.

Mr. A. M. Kennedy mentions a method often adopted for the repair of fractures in the stern frame. In old ships the propeller aperture is unduly long and large fractures frequently develop at the solepiece. Rather than fit welded slabs all around, a heavy steel soleplate fitted to the underside, overlapping about 3 in. on each side and fillet welded to the solepiece, gives a solid reinforcement where most needed. The plate should be tapered off in width and thickness at the ends to avoid an abrupt change of section. The welded fractures are visible at subsequent docking surveys.

Mr. D. S. Forsyth's opening sentence should be memorised by all young surveyors, viz., "Severe wastage can be found generally and especially between wind and water, and where there is inadequate ventilation, damp, heat and abrasion; also in any inaccessible positions where there is consequently lack of maintenance." A typical example is the wing ballast tanks fitted port and starboard of the engine room of Standard (War II) Merchant Ships. Every such tank I have examined internally has been in an appalling condition due to inadequate ventilation, damp and heat. Similarly, in the boiler room double bottom tank,

especially if there is no lagging on the lower boiler shell and no bituminous (heat insulating) composition on the tank top.

Other positions not specifically mentioned in the symposium where severe wastage or defects can be anticipated, or requiring special attention, are as follows:—

SHELL BILGE STRAKE (with side bilges). From margin plate shell bar to frame cement chocks.

SIDE PLATING. Abreast of boilers, crews lavatories, deep tanks, engine room stores with lockers at ship side, domestic refrigerated chambers, also at oxter plates and stern tube boss plating.

NOTE—The permissible wear for individual plates is briefly set forth in the instructions to Exclusive Surveyors. Generally, however, in the case of old ships built prior to 1922, shell plates would not require renewal until reduced below 33⅓ per cent of the original thickness. But for vessels built after 1922, owing to the reduced original thickness under revised Rules, a lesser percentage of wear is permissible. As a general guide applicable to shell, also deck and tank plating, of original thickness of ·20, ·30, ·40, ·50, ·60, ·70, ·80, ·90 and 1·00 in. the respective renewal thickness would be about ·15, ·22, ·29, ·35, ·42, ·48, ·54, ·59 and ·64 in. (ships built after 1922). As a rough estimation of the original thickness of ordinary shell plates amidship for a full scantling ship, add 200 ft. to the length of the ship and divide by 1,000, obtaining thickness in decimals of an inch (approx.).

An examination of the internal surfaces after removal of a condemned shell plate in way of peak tanks, fore hold or bunkers, etc., will clearly demonstrate the grooving and corrosion to be carefully looked for at heel of side framing, side stringer shell lugs, etc. Thorough scaling and coating at such locations is essential at Special Surveys.

TRANSVERSE BULKHEADS. In way of lower hold side bilges. Also in way of side ballast tanks and the port after end of machinery space where pumps, piping and distribution valve boxes are usually located and very inaccessible for maintenance.

'TWEEN DECKS. Immediately above boilers.

TUNNEL WELL. Floors, centre girder, lower end of side frames, also aftermost double bottom tank end and lower parts of after peak bulkhead not so conveniently accessible when examining these tanks internally. Check condition of tunnel recess plating and supports for possible deformation from heavy concentrated cargoes above.

CHAIN CABLES. No particular length can be taken for granted. Requires careful calipering to obtain mean average diameter. Check efficiency of end attachment to chain locker plating.

NOTE—Even if a vessel has no figure "1" for equipment, serious deficiencies in equipment may jeopardise the vessel's seaworthiness and whole Class. At Special Surveys the regulations require the Surveyor to report upon the actual equipment on board.

ALL PIPING. Requires thorough examination especially at bilge, in way of protective casings, after peak suction, piping passing through deep tanks, etc.

BOILERS. Attachment of safety valves and mountings to shell and end plate (studs and nuts).

Valves for excessive machining down of seats and serious reduction of wall thickness of chest.

Furnaces (difficult to estimate thickness by hammer testing), ascertain thickness by drilling and gauging old furnaces if general wastage and corrosion is suspected.

Check thickness of end plates at root of flanging of lower circumferential seams, flanging of manhole openings, also shell, for possible slight leakage and local wastage at concealed or inaccessible parts.

Back tube plates for corrosion on water side in way of tubes.

MACHINERY. All ship side valves and their fastenings to shell, suction boxes, and piping connected to underwater sea valves, bilge injection, pumping arrangements, steam piping, main engine holding down bolts are some items requiring very special attention.

NOTE—When steam piping is removed for testing it is important that the central hole in the jointing material be larger than the outside diameter of the steam pipe to ensure a pressure test of the attachment of flange to pipe—a common defect.

GENERAL. During the survey of a very old ship certain parts of the ship structure may be found worn to almost the renewal size, becoming a borderline case. It may be a general or serious condition where renewals would entail a most costly and inconvenient repair, such as to tank margin plating, bilge bracket plates, reverse frames, or floors and intercostals, tank top plating in way of

engine and boiler room double bottom tanks, the web part of main side framing, exposed weather deck plating, etc. This is a situation where the Surveyor must use his experience and a wise discretion to decide what must be renewed, strengthened, reinforced, or left as it is. In cases where you inform the Owner that you are prepared to leave certain parts intact subject to being very thoroughly scaled, cleaned and recoated with a special quality protective coating to ensure no further undue diminuation of thickness during the next four years, he is more than happy to comply.

T. S. FATKIN

The Symposium on the subject of "The Survey of Very Old Ships" made very interesting and instructive reading and it is felt that the various problems and trouble centres arising from such surveys have been very efficiently aired and presented by the contributors.

The following two cases are good examples of what may occur when, to quote Mr. Kraayenbrink, the angels desert the Surveyors' shoulders, and are given to illustrate points already covered by the paper.

The first concerned a 1929 built coal burning vessel (not so very old) of 370 ft. B.P. length having long bridge and single deck. The Superintendent complained of a fracture in the bridge deck stringer plate (starboard side) amidships and it was found to be fractured about 12 in. athwartships in line with the after end of a mooring bollard base. The bridge deck plating generally was found in fairly good condition, but there was evidence of grooving at the sight edges of the butts.

On examination of the bridge 'tween deck bunkers, however, the strake of main deck plating adjacent to the stringer was found to be fitted with a welded doubler for full width over two plate lengths (port and starboard) and the main deck was found fractured (starboard side) athwartships at the after end of the doubler. The fracture also ran forward along the outboard edge of the doubler through the stringer plate. The stringer plate had been doubled throughout the length of the bunker for a width of 15–18 in. at shell only.

The doubler of the inboard strake was found to have no connection to the main deck beams and examination of the underside (in way of the boiler room) showed it to be riding freely over the beams and remnants of the original plating. All that held the doubler in place was the peripheral weld.

Whilst on the boiler tops, examination of the channel side frames showed the standing flange of five or six (port and starboard) to be practically non-existent for about 4 ft. from centre of beam knee down.

The moral to this case, and indeed any such case, could be written: "Never accept a fracture on its face value".

The second case concerned a 1920 built ship 380 ft. B.P. length with longitudinal framing.

This vessel with a full cargo of coal had to put back to port on encountering fairly heavy weather with the fore peak tank full after being dry on departure and a 17 ft. sounding of the water in No. 1 Hold pulling down her about 8 ft. by the head. After complete discharge of cargo from No. 1 Hold two plates (1 port and starboard) were found to be fractured in the fore peak and one plate in No. 1 Hold all along the heels of the longitudinal frames on account of wastage and grooving.

Examination of the shell after chipping and scaling along the heels of frames throughout the panting area showed the plating to be severely wasted and grooved, especially where pockets were formed in way of the frames passing through the transverses. At these particular places drill tests showed thicknesses ranging from 0·1 in. to 0·20 in.

In this case each strake of shell plating took two longitudinal frames and eight plates were found to be so badly grooved that their renewal was the only solution. It should be added that before chipping and scaling took place the affected shell plates had every appearance of being perfectly sound.

PRINTED BY LLOYD'S REGISTER OF SHIPPING
AT GARRETT HOUSE
MANOR ROYAL, CRAWLEY, SUSSEX, ENGLAND

MAY, 1954

PRIVATE AND CONFIDENTIAL

LLOYD'S REGISTER STAFF ASSOCIATION

SESSION 1952-53

THE REPAIR OF WELDED SHIPS

A SYMPOSIUM

LLOYD'S REGISTER OF SHIPPING,
71, Fenchurch Street,
LONDON, E.C.3.

The contributions to this symposium have been edited by the Reading Committee of the Staff Association who wish to apologise to contributors for any omissions which have been found necessary in the interests of economy or to avoid redundancy.

THE REPAIR OF WELDED SHIPS

A SYMPOSIUM

MR. P. F. BALFOUR, DURBAN

Welders.

IT is well known that one of the most important factors is the personnel who do the actual welding. In this country there is no testing authority by which all welders can be passed as satisfactory. The ship repair firms have their nucleus of reliable welders, a number of which are first class artisans. It has been my experience that, when a rush of repairs comes into the port, and there is a major repair job on an all-welded ship, one must give the work very careful supervision, owing to the fact that extra men who have been recruited as welders are, in some cases, far from satisfactory. In cases of this type, it is advisable to request repair firms to have these welders make test welds, which will give some indication of their ability. It is also a good policy to impress upon repair firms the importance of having adequate supervision.

Workmanship.

I have noted that, when dealing with staggered or intermittent welds, there is, at times, a tendency to be careless, with the spacing of welds. This is quite unnecessary, as it is a simple matter to supply the welder with a template, with which he can check his own work.

Cutting Out of Damaged Plating.

In the case of riveted ships, when cutting out defective or damaged plating, due regard is given to shift of butts, but I have frequently found that there is a tendency to disregard this entirely with all-welded ships, and it has often been suggested to the surveyor that it is only necessary to cut out that panel of plating which is actually damaged, e.g. a sharp indent and fit a new panel, without any regard to adjacent butts or seams.

Stress Relieving.

I have often been asked whether it is good practice to stress relieve welded repairs by means of a blow torch, but I am of the opinion that this local stress relieving is not of much value. I should be glad to read the views of my colleagues on this subject.

MR. W. M. BALFOUR, BELFAST

Experience regarding repairs to the all-welded ship for wear and tear is still very limited, and the following remarks refer to damage repairs only.

If Owners are willing to repair welded ships by means of insert plates regardless of welded seams and butts the repair is simple, once the welding technique and sequence to be followed is clearly understood by the platers who have to prepare the job, and by the welders who have to complete the job.

Fillet welds attaching the supporting members to the plate cannot be cut out with the normal pneumatic tools, but an experienced flame cutter can manage to make a reasonable job of removing a fillet weld and should be followed by a caulker dressing up. The simplest method, however, is to cut the supporting member just above the fillet weld and insert a tee piece on the completed job.

Where, however, Owners object to fitting insert plates regardless of seams and butts, the repair work is complicated and renewals are extensive, because it is unsatisfactory to recommend a plate with welded seams and butts and fully welded to the supporting members to be removed, faired and refitted.

MR. D. S. FORSYTH, GOTHENBURG

It may well be re-stated here that our general experiences confirms that if the Recommendations laid down by the Admiralty Ship

Welding Committee both as regards new and repair work could be generally ensured then most, if not all, of the defects which arise would in all probability be overcome.

The following are certain points which might bear emphasis :—

1. Fractures of forecastle deck plating around the toes of bulwark stiffeners, and to a lesser extent hatch coaming stays, occur where these quite often have not coincided with the beams below, or if they have, may have landed in way of a scallop.
2. Similarly fractures in bulkhead plating are often found where toes of brackets in alignment with stiffeners on opposite side land in way of scallops.
3. Local part renewals of plating, etc., can be too restricted and unless considerable care is taken new fractures may develop.
4. Similarly not adequately cutting back adjacent welding to effect repairs, and also improper sequences and undercut can be sources of further trouble.
5. The danger of too stiff re-inforcement or doubling in relation to original material and its disposition; also excessive local concentrations of welding should be avoided.
6. Overcuts at corners of any type of opening instead of burning to drilled holes or preferably adequate radii.
7. Abrupt changes of section and point loads such as engine girder seatings to adjacent tank tops, girders abutting decks or flats, bulkheads crossing bulkheads or girders underneath.
8. Mal-alignment especially in way of corrugated bulkheading.

Sketches, Figs. 1 to 27, show typical fractures and repairs.

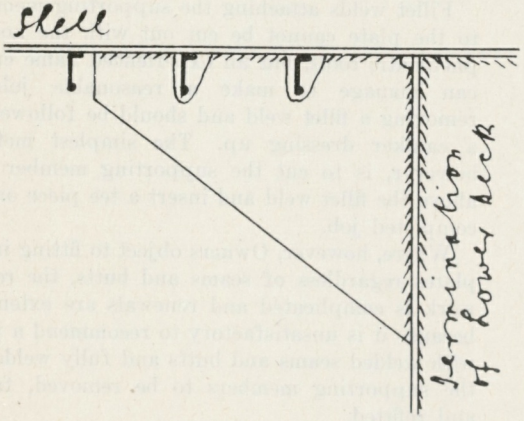
MR. T. F. NAISBY, YOKOHAMA

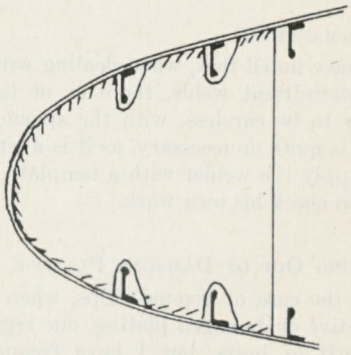
It is suggested that a riveted connection of girder to strength deck between hatchways should not be allowed if the girder in way of hatch side is directly welded to the deck.

This arrangement obtained in a ship recently built which sustained serious deck fractures at hatch corners. The change over from welding to riveting occurred abruptly at the hatch ends.

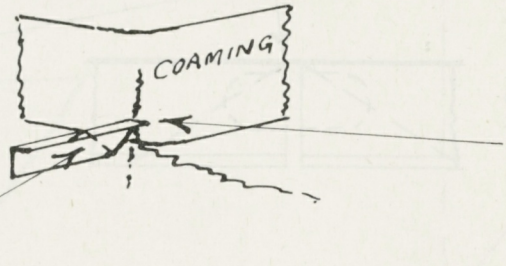
Similarly where the girder between hatches is intermittently welded to the deck the continuous welding in way of the hatch should be continued past the hatch ends for at least one beam space.

It is well to avoid arrangements similar to those shown in the following sketch. The frames and brackets will work independently of each other, whether we want them to or not, inevitably causing fractures sooner or later.





1. Winch seating outer girder in line with hatch side coaming and welded thereto



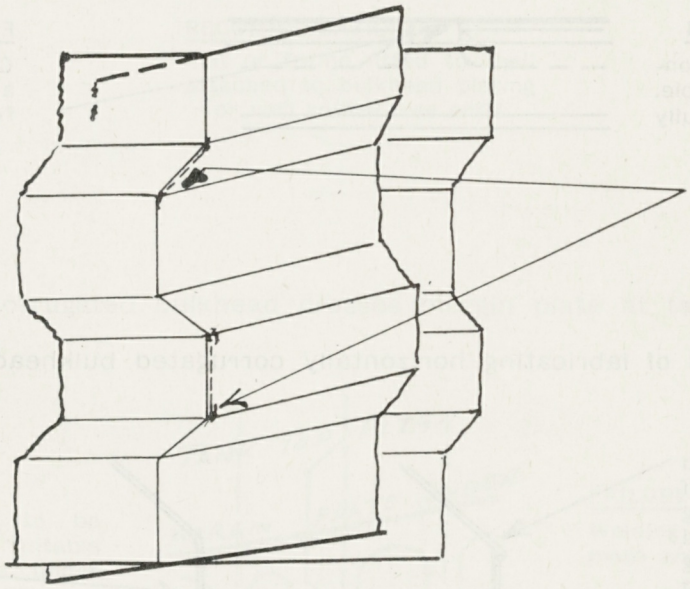
RECOMMENDATION

Crop winch girder clear from coaming. Such a girder (outer) should not be attached to coaming

FAILURE

Toe weld fracture extends into hatch coaming, into deck plating and also through underdeck girder

2. Horizontally corrugated bulkheads abutting bulkheads which may be corrugated or plain



RECOMMENDATION

Releasing and fairing or part renewal. Pilot holes for careful alignment during erection

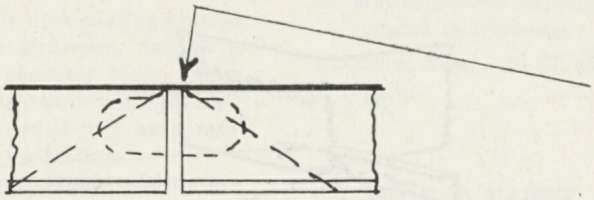
FAILURES

Fractures at knuckles found mainly due to mal-alignment of the bulkhead plating which is cut

3. Bilge Keels

RECOMMENDATION

Bilge keel break softened with scallop or well tapered back

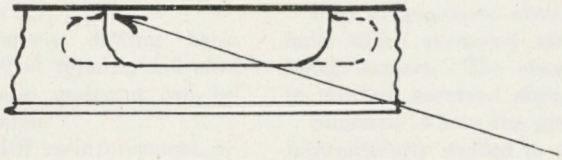


FAILURE

Shell plating fractured at break in bilge keel

RECOMMENDATION

Soften opening ends by suitable scalloping

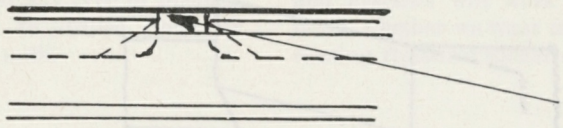


FAILURE

Fracture in shell plating

RECOMMENDATION

Shell connection continuous if practicable, otherwise carefully sniped



FAILURE

Caulking, corrosion and subsequent fracture in shell plating

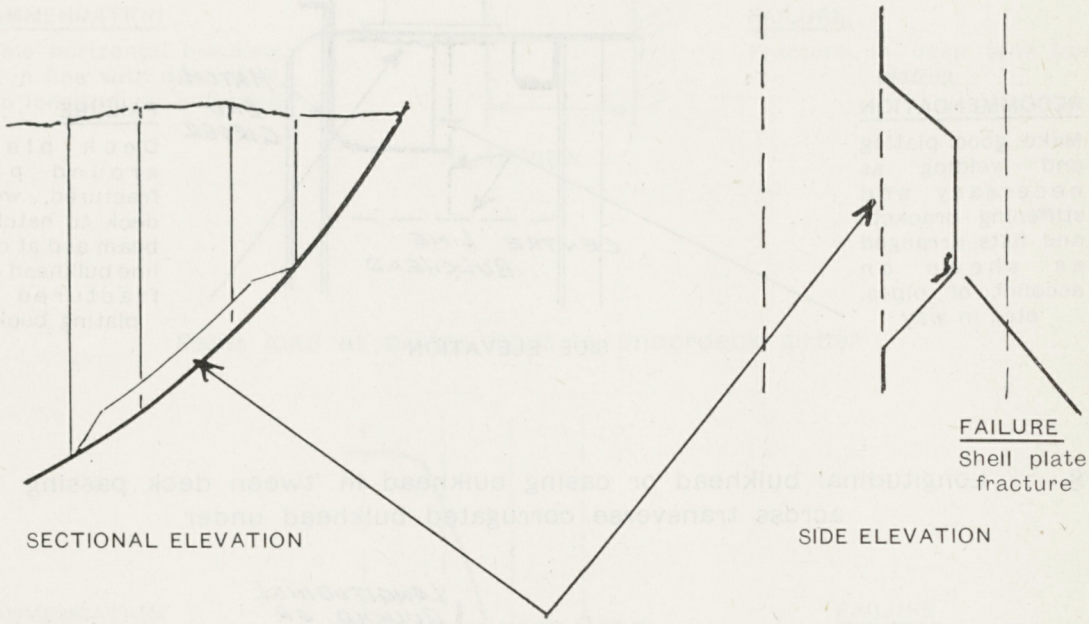
4. Method of fabricating horizontally corrugated bulkhead plating

Evidence found that this type of joint resulting in stressing and corrosion of plating adjacent to weld may well result in future fractures

This type preferable, and now more usual

SECTION

5. Insufficiently supported shell panels in way corrugated bulkheads



SECTIONAL ELEVATION

SIDE ELEVATION

FAILURE

Shell plate fracture

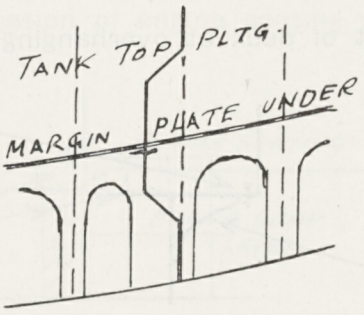
RECOMMENDATION

Flat or frame fitted to shell attached to bulkhead plating or well sniped free ends

6. Where corrugated bulkhead crosses margin plate at tank top

RECOMMENDATION

Fractured welding to be made good but suitable reinforcing bracket under possibly advisable

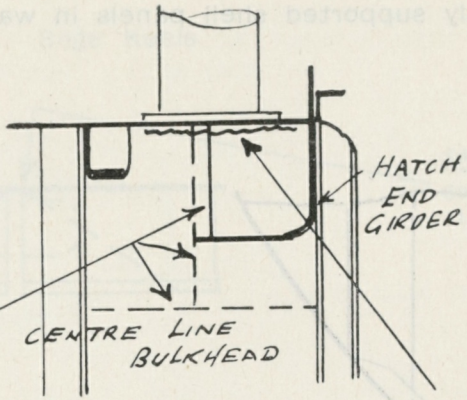


PLAN VIEW

FAILURE

Welding between margin plate and tank top plating fractured

7.



SIDE ELEVATION

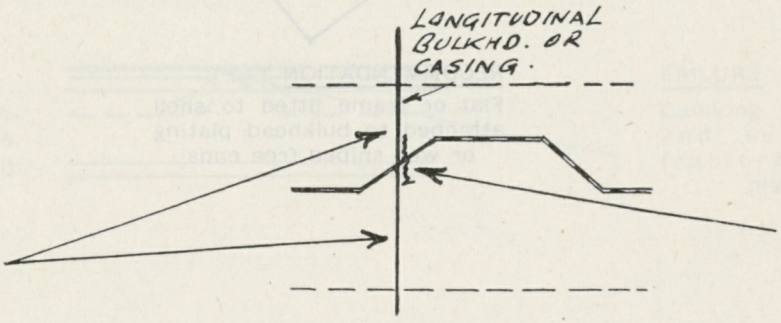
RECOMMENDATION

Make good plating and welding as necessary and stiffening brackets and flats arranged as shewn on account of pipes, etc., in way

FAILURE

Deck plating around pillar fractured, welding deck to hatch end beam and at centre line bulkhead under fractured and plating buckled

8. Longitudinal bulkhead or casing bulkhead in 'tween deck passing across transverse corrugated bulkhead under



PLAN VIEW

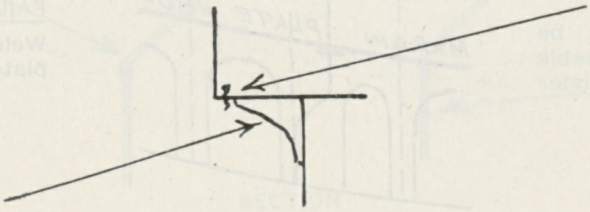
RECOMMENDATION

Suitable fore and aft reinforcing brackets under

FAILURE

Fractured deck plating

9. Support of deck at overhanging casing.



SIDE ELEVATION

FAILURE

Fractured deck plating

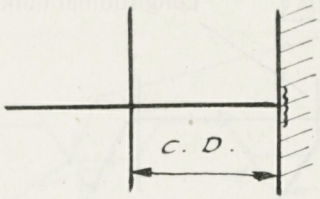
RECOMMENDATION

Extended brackets to support casing bulkhead

10. Longitudinal bulkhead plating abutting deep tank top plating

RECOMMENDATION

Suitable horizontal brackets fitted in line with deep tank top to longitudinal bulkhead



PLAN VIEW

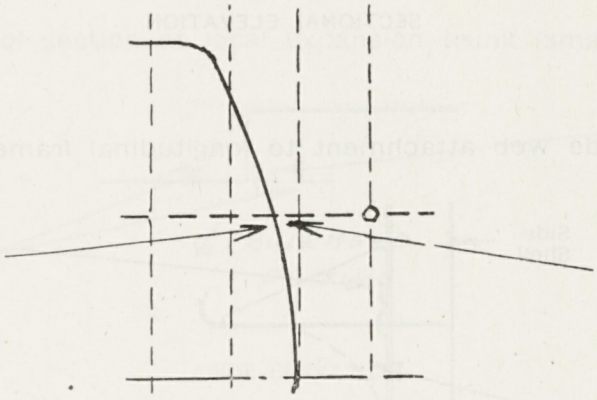
FAILURE

Fracture in deep tank top plating

11. Point load at bridge front to underdeck girder

RECOMMENDATION

Beam slots reinforced, suitable brackets and reinforcement to pillar



PLAN VIEW

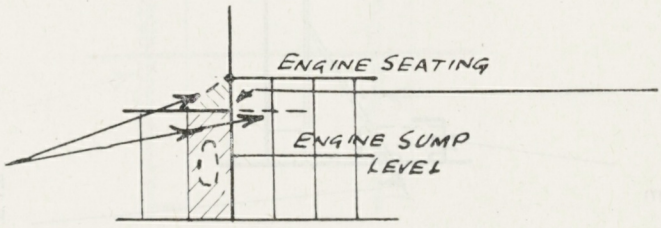
FAILURE

Fractures in girder web plates at beam slots

12. Termination of engine seating girders.

RECOMMENDATION

Additional intercostal plate and vertical and horizontal brackets

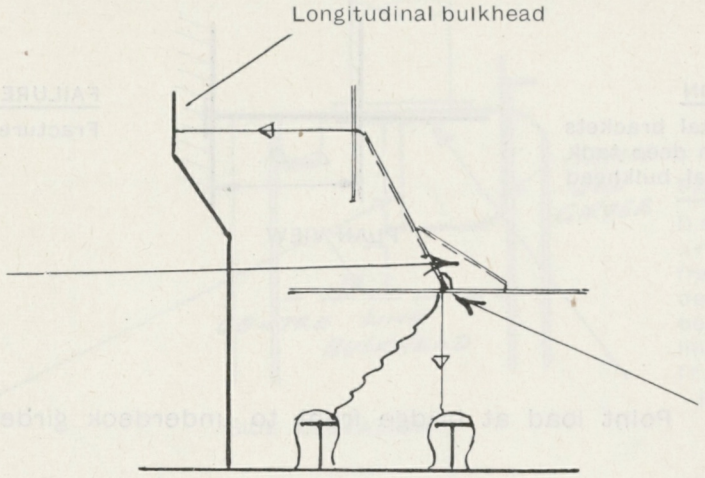


ELEVATION

FAILURE

Small vertical and horizontal fractures in tank top and floor plating (p. & s.)

13. Bottom transverses in centre cargo tanks



RECOMMENDATION

Extension brackets Fitted.

This type of construction now altered

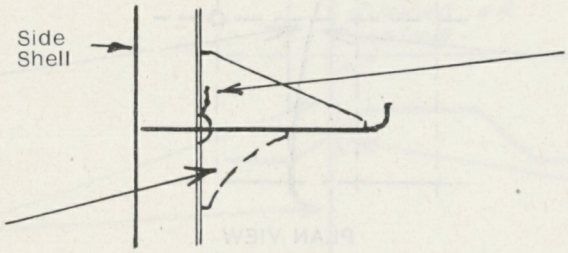
FAILURE

Fracture commencing at weld concentration and extending down to frame slots.

Fractures (similar) also in side tanks

SECTIONAL ELEVATION

14. Side web attachment to longitudinal frames



FAILURE

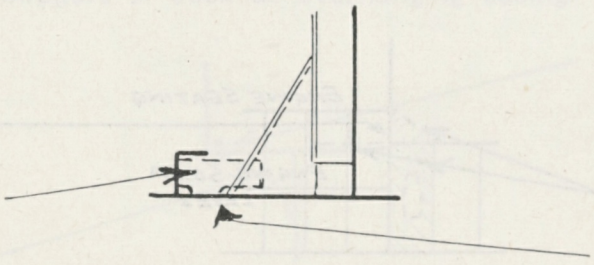
Fracture along bracket to longitudinal frame

RECOMMENDATION

Additional brackets

PLAN VIEW

15. Transverse bulkhead stiffener bottom brackets to shell



RECOMMENDATION

Extension flats from brackets to frame

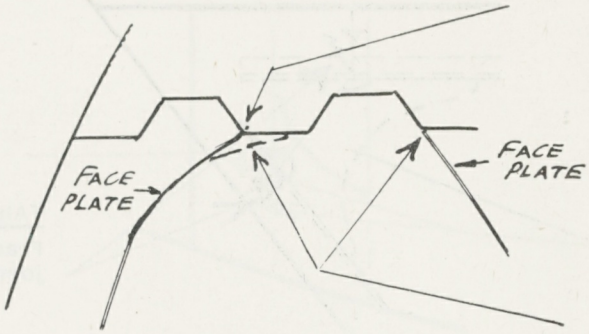
FAILURE

Fracture in shell plate

SIDE ELEVATION

16. Stringer and girder attachments to corrugated transverse bulkheads

FAILURE Fractured bulkhead plating



RECOMMENDATION

Face plates well sniped away and hollow bracket fitted in case of stringer connection

PLAN VIEW

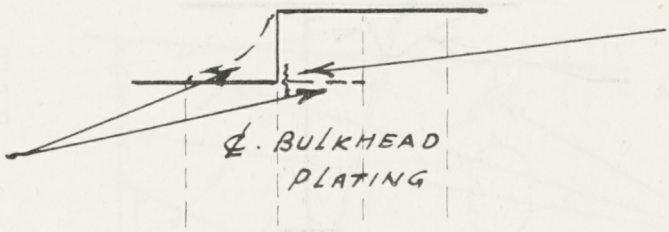
17. Change of section at local expansion trunk (small tanker)

FAILURE

Centre line bulkhead plating fractures

RECOMMENDATION

New vertical and horizontal brackets

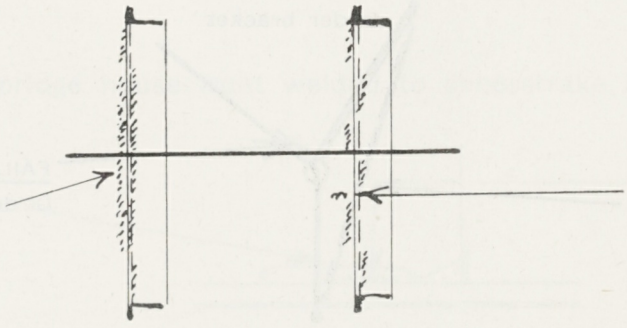


SIDE ELEVATION

18. Bulkhead plating in way $\frac{1}{2}$ depth stringer girder (inverted stiffeners, intermittent welding) (small tanker)

RECOMMENDATION

Continuous welds made adjacent to stringer girder and all stiffener girder welds overhauled

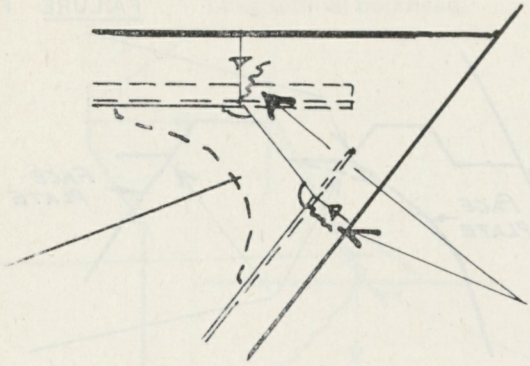


FAILURE

Fractures in plating. Starting at intermittent welds

SIDE ELEVATION

19. Welded beam knees



RECOMMENDATION

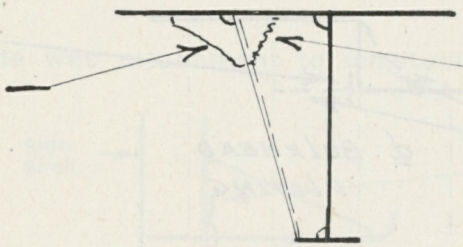
Extended hollow brackets

FAILURE

Fractures at welded joint, especially forward hold

SECTION

20. "Small" softening bracket to vertical web supporting brackets



RECOMMENDATION

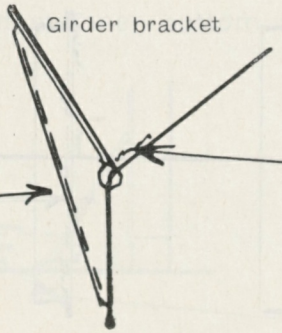
Larger hollow bracket

FAILURE

Fracture through bracket and into bulkhead plating

PLAN VIEW

21. Centre line underdeck girder bracket to transverse bulkhead in pump room



RECOMMENDATION

New bracket

FAILURE

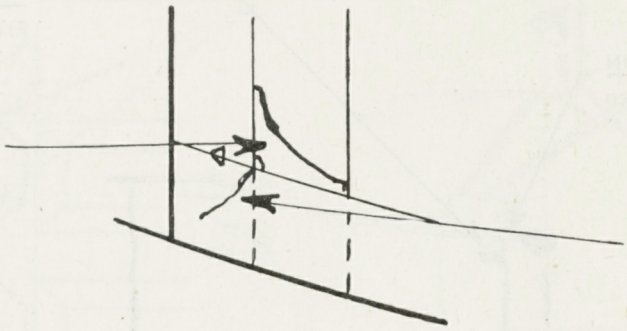
Girder bracket fracturing

SIDE ELEVATION

22. After peak tank stringer plate

RECOMMENDATION

Additional hollowed bracket



FAILURE

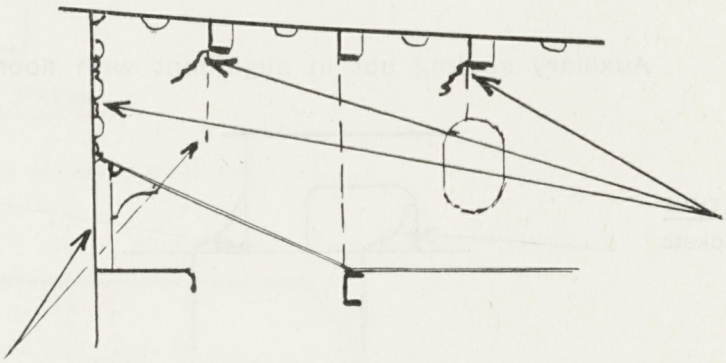
Stringer fracturing

PLAN VIEW

23. A. peak wash bulkhead plate

RECOMMENDATIONS.

New vertical stiffener and hollowed bracket and well sniped stiffening flats to intermittent beams



FAILURE

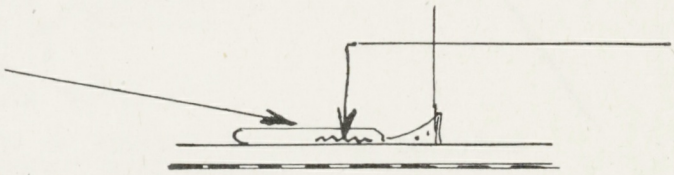
Fractures in washplate and end welding to A.P. bulkh'd

SIDE ELEVATION

24. Rounded bridge house front welded to sheerstrake at side

RECOMMENDATION

House front foundation flat cut clear of sheerstrake and side plating efficiently slotted back



FAILURE

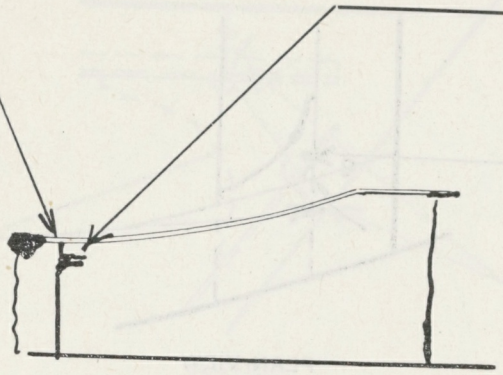
Fracturing

SIDE ELEVATION

25. F. & A. girder between boiler stools

RECOMMENDATION
Small bracket to stool face flat

FAILURE
Fracture in stool plate

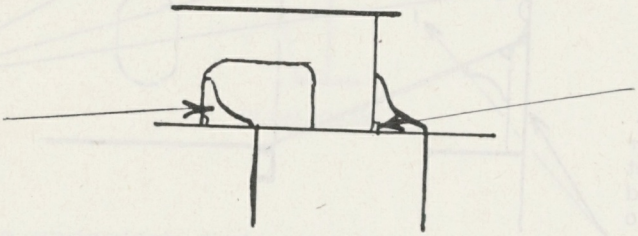


ELEVATION

26. Auxiliary seating not in alignment with floors

RECOMMENDATION
Extension brackets

FAILURE
Fractures in tank top plating

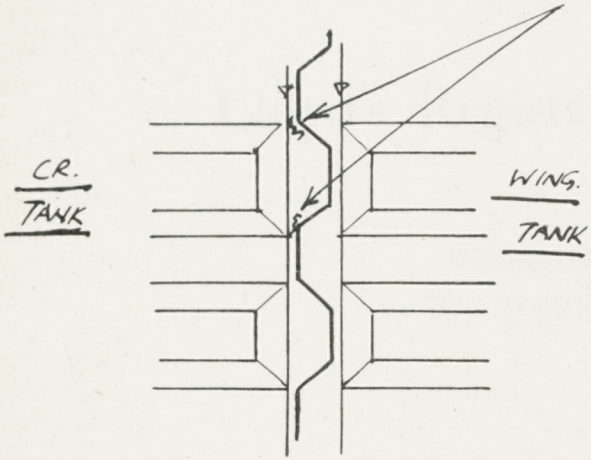


SIDE ELEVATION

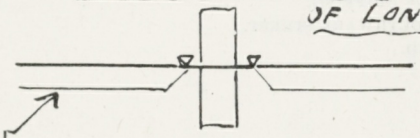
27.

FAILURE

Small fractures occurring in centre tanks only (Hard corner)

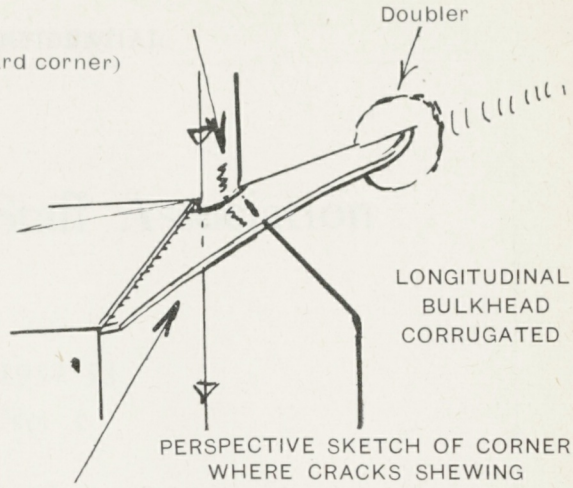


SECTIONAL ELEVATION OF LONGITUDINAL BHD.



PLAN VIEW

TROUGH CORRUGATION



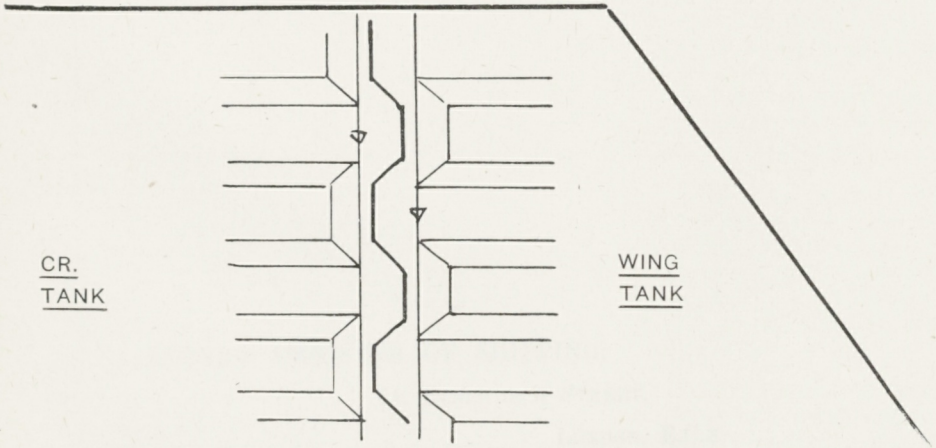
PERSPECTIVE SKETCH OF CORNER WHERE CRACKS SHEWING

RECOMMENDATION

Hollowed brackets fitted from inclined panel of trough corrugation to longitudinal corrugated bulkhead with local doubling at toe on latter

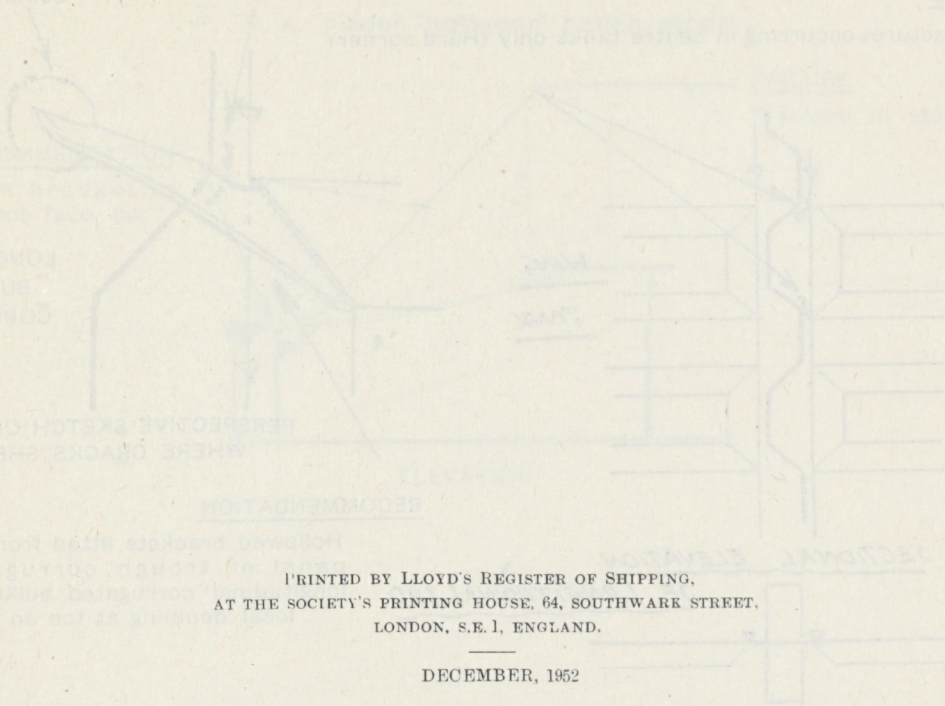
NOTE :—Longitudinal bulkhead cut and welded at the vertical panel in transverse bulkhead

28.



SECTIONAL ELEVATION OF AMENDED TRANSVERSE BULKHEAD TROUGH CORRUGATIONS

NOTE :—Disposition of troughs in centre tanks amended in a later sister ship as per wing tank arrangement where no cracks have yet been experienced



PRINTED BY LLOYD'S REGISTER OF SHIPPING,
AT THE SOCIETY'S PRINTING HOUSE, 64, SOUTHWARK STREET,
LONDON, S.E. 1, ENGLAND.

DECEMBER, 1952

PRIVATE AND CONFIDENTIAL.

Lloyd's Register Staff Association

SESSION 1952-53

PAPER No. 1

DISCUSSION

on

Symposium

THE REPAIR OF WELDED SHIPS

LLOYD'S REGISTER OF SHIPPING,
71, FENCHURCH STREET,
LONDON, E.C.3

The Author of this paper retains the right of subsequent publication, subject to the sanction of the Committee of Lloyd's Register. Any opinions expressed and statements made in this paper and in the subsequent discussion are those of the individuals.

Discussion on Symposium

THE REPAIR OF WELDED SHIPS

G. S. MILNE

This is a most interesting paper to Surveyors concerned with hull construction and repair.

The Authors deserve our congratulations and thanks, but it is a matter for regret that more contributions have not been received.

Surveyors responsible for new construction would have welcomed more information on the faults which welded ships are showing, and the period in service of these ships prior to the faults becoming evident.

From reports of casualties in the daily technical press, as reported by Salvage Association Surveyors and others, we hear of such damages as "The usual cracks in transverse and longitudinal bulkheads made by welding and doublings". The word usual is disturbing.

The faults shown in Mr. Forsyth's contribution show clearly that defective design is a much more potent cause of trouble than bad workmanship. The only clear instance of a fault arising from bad workmanship is shown in Fig. 14, a crack commencing from a notch where it is difficult to weld around the plate edge. The other defects I venture to say are primarily due to design unsuited to welded construction, causing stress concentrations due to rapid change of section, point loading and insufficiently supported plating at points of high loading.

According to experimental evidence, under conditions conducive to corrosion fatigue (and it is assumed such conditions obtain in tanker bulkhead connections and elsewhere), a surprisingly low stress is sufficient to cause fracture, this stress decreasing progressively with increase in number of reversals.

It would be unwise to assume complete freedom from defects in ship welding even under the best conditions, and I consider that the design should be such as to allow for a standard of welding compatible with good production welding on the ship. From the information given in this paper and experience on new construction it is evident that the greatest scope for advancement in welded ship construction now lies in design. The idea that a successful riveted design will be an equally successful welded design dies hard, particularly with shipbuilding firms who are anxious to avail themselves of all the advantages of welded construction without incurring the disadvantages arising from the more elaborate and expensive design of connections essential to good welded construction. Face area of girders, brackets, etc., formed by flanging plates is an example.

In regard to faults enumerated by Mr. Forsyth, I would suggest that the fractures shown in Fig. 2 may be due to both bulkheads being corrugated horizontally, thus giving inadequate resistance to shear forces. In Fig. 5 may not the fracture in the shell plate be due to a combination of transverse stress and bulkhead bending stress? From the sketch it would appear that end fixing moments at the shell connection of the bulkhead are effected by the shell plating only. It is suggested that a plain bulkhead with stiffeners is a more efficient design in this area.

In Fig. 6 I would consider that reinforcing brackets or some other means of spreading the load are necessary.

I have an uneasy feeling that rectifying faults in welded ships by small "softening" brackets or additional reinforcement by flats, etc., is merely a palliative and that in course of time, other fractures will occur in the same area. Perhaps one of the Authors would care to comment on this.

This contribution may seem to be over critical of certain features of welded ship design. However, with so many variable and indeterminate forces acting on a ship "the proof of the pudding must be in the eating". Unfortunately the period of digestion in the case of a ship is a protracted one, and in the

meantime defects may be repeated in many ships before sufficient proof is available to convince Owners and Builders that it is not wise to allow saving in steel weight or labour costs to influence the design to such an extent that maintenance costs outweigh any initial advantage.

N. M. KISSELL

I agree with Mr. P. F. Balfour, Durban, that a test should be carried out. As an example:—

Repair to all welded Liberty-type of ship. In a major damage repair a request for routine welding tests was made with the suggestion that they should be:—

(A) Factory (F) material to Factory (F) material

(B) Factory (F) material to Ship (S) material

(C) Ship (S) material to Ship (S) material

The results were really alarming, especially the bend tests. Etching showed an apparently good weld, but in our first ten tests F to S and F to F eight failed, some of the bends at about 15 degrees. The electrodes used were immediately suspect, but these on test, tensile and bend, were found good. The factory material was also tested and found efficient. Six different approved electrodes were tried and procedure checked before good results were obtained, in all about thirty tests were made.

The motto is carry out routine tests before effecting *extensive* welding repairs, especially if the material is not exactly of the highest grade.

W. RENNIE

At many repair yards the Surveyor requires to be especially alert to catch up with welders who are not proficient, turning out a poor standard of workmanship, and even the supervisors for lack of observance to correct welding procedures and sequence. Many welders on the job have the idea that distortion and locked up stresses are caused by welding two separate pieces of plate together. It is a good idea to give him a piece of bent plate and straighten it merely by welding on the surface.

It is proposed to mention two small but considered to be important points in connection with the welding of small fractures at shell and bulkhead plating now all too prevalent with some types of all welded tankers.

After normal preparation of the fracture for a vee butt weld with minimum gap, the plating should be forced apart with a narrow steel wedge causing compression of the plating. After partial welding by the skip or step back method, the wedge is removed and the contraction stress of the weld largely balanced and free of residual stress when completed.

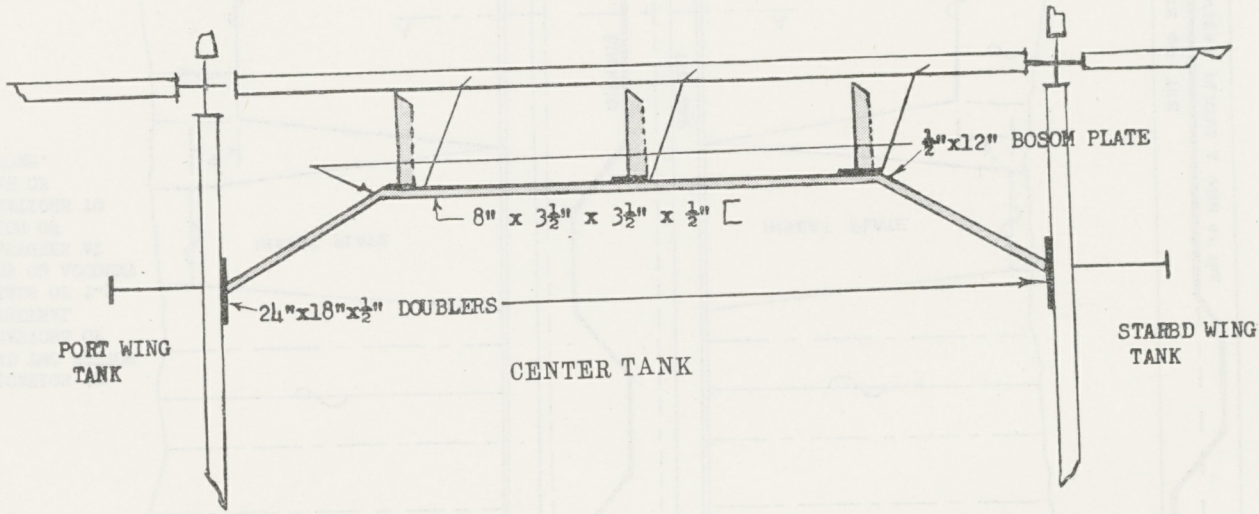
Similarly, when it is necessary to fit a local welded doubling plate to shell, deck or bulkhead plating the welding stresses are largely relieved if the doubling plate is slightly dished away from the faying surface before welding in position. If a narrow panel of plating is being renewed by two butt welds, the panel plate should be slightly dished, one butt weld fully completed whilst the plate is unrestrained and the second weld then completed. The contraction stress will straighten out the plate and both welds will be without any pronounced residual stress.

It is considered that no pneumatic tools should be used in the vicinity, say 20 ft., whilst an important structural weld is being performed and the deposited molten metal cooling off. Pneumatic tools set up vibratory stresses of varying intensity, especially on the lighter plating. I witnessed tests (1938) demonstrating that butt welds made by a highly-skilled welder fractured across the weld whilst vibratory stresses were imposed by a pneumatic machine. There are neutral positions and it is not dependent upon distance away from the welder, but 25 ft. is a safe maximum.

W. C. COWIN

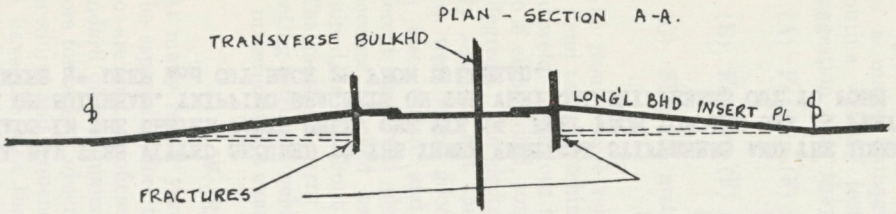
The following sketches show repairs to the bulkheads of T-2 Tankers that have been adopted by some Owners as standard practice.

T-2 TANKERS TRANSVERSE BULKHEADS.

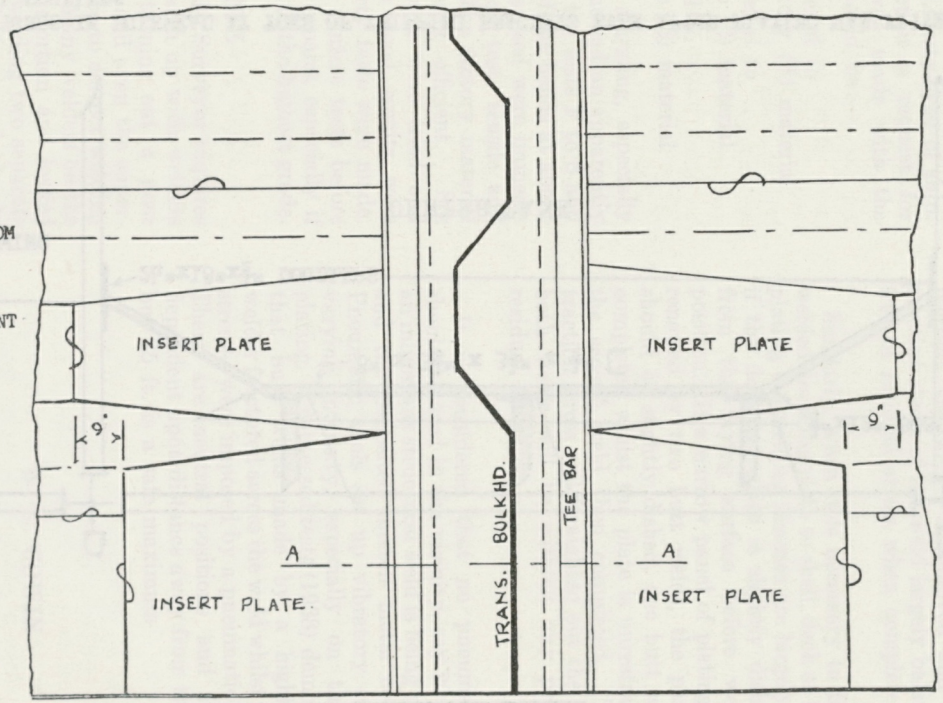


FRACTURES IN BULKHEAD AT TOES OF TRIPPING BRACKETS EVEN AFTER PLATING WAS FITTED WITH LOCAL DOUBLERS.

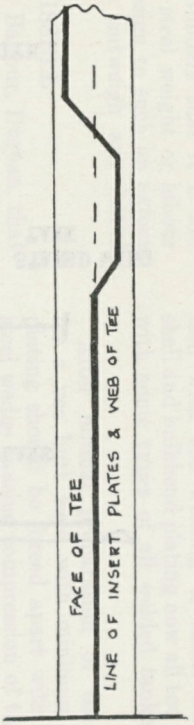
CHANNEL BAR TIES FITTED SECURED TO THE THREE VERTICAL STIFFENERS AND THE LONGITUDINAL BULKHEADS IN THE CENTER TANKS ONLY. ONE TIE 15 FEET FROM TOP AND ONE 15 FEET FROM BOTTOM OF BULKHEAD. TRIPPING BRACKETS ON THE VERTICAL STIFFENERS CUT TO FORM BAR STIFFENERS 4" DEEP and CUT BACK 2" FROM BULKHEAD.



MODIFICATION TO TOP AND TWO BOTTOM CORRUGATIONS OF LONGITUDINAL BULKHEADS OF T-2 TANKERS ON ACCOUNT OF FRACTURES AT JUNCTION OF CORRUGATIONS TO TEE BAR OF CRUCIFORM.



ELEVATION.



SECTION

PRINTED BY LLOYD'S REGISTER OF SHIPPING,
AT THE SOCIETY'S PRINTING HOUSE, 64, SOUTHWARK STREET.
LONDON, S.E.1, ENGLAND.

OCTOBER, 1953